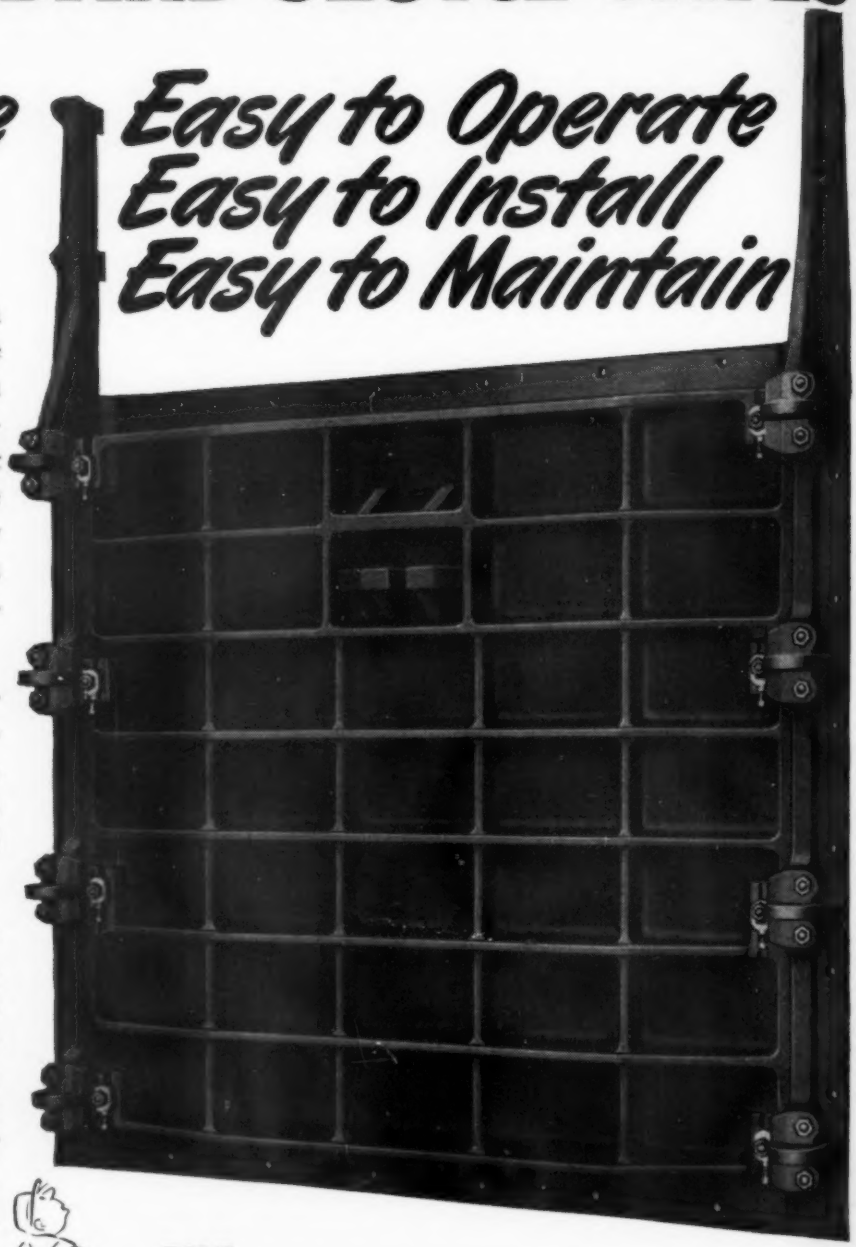
WATER & SEWAGE WORKS

CHAPMAN

STANDARD SLUICE GATES

Are Easy to Operate
Easy to Install
Easy to Maintain



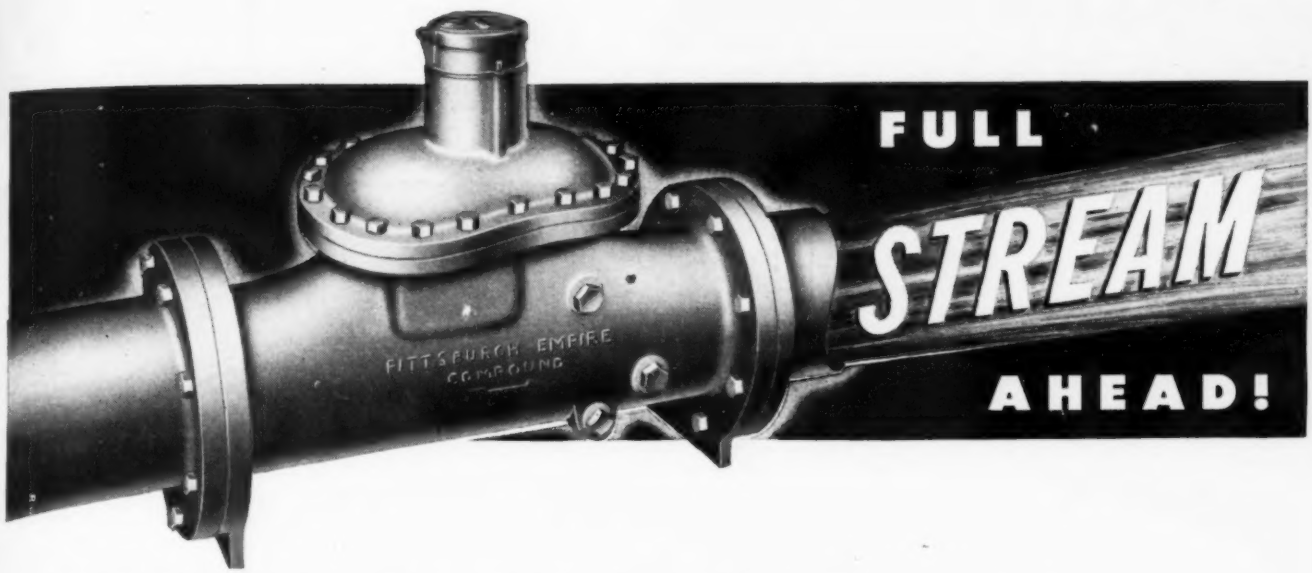
There's no operation problem with Chapman Standard Sluice Gates . . . they're available with any one of three types of operating control—manual, hydraulic cylinder, or motor unit. The motor unit is wired at the factory—ready to install, and has a handwheel for emergency operation should power fail.

All stems and couplings are completely interchangeable and therefore require no match-marking. All repair and replacement parts can be easily installed in the field without alterations.

Remember, Chapman has a complete line of Sluice Gates which are designed to meet all the usual conditions . . . and many so-called special patterns are included. You can usually find what you need in the Chapman Standard Line; if not, Chapman engineers will be glad to work with you on your special problems. Write today for full information.

THE
CHAPMAN VALVE Mfg. Co.
INDIAN ORCHARD, MASSACHUSETTS

WATER AND SEWAGE WORKS, July, 1947. Volume 94. Number 7. Published monthly by Gillette Publishing Co., 22 West Maple Street, Chicago, Ill. Per copy, 25c, except *this issue* 75 cents. Subscription rate, United States, $2.00 per year; Canada, $2.00 per year; Foreign, $3.00 per year. Entered as Second Class Matter, March, 12, 1946, at the Post Office at Chicago, Ill., under act of March 3, 1879.



NO BRAKES ON LINES FITTED WITH

PITTSBURGH - EMPIRE *Compounds*

The Pittsburgh-Empire Compound largely eliminates the pressure loss bottleneck that has previously been a trial on lines fitted with compound meters. Alone among meters of this type, the Pittsburgh-Empire has a straight through flow passage for all volumes measured by the propeller unit. (See diagrams below).

Two design features make possible minimum pressure absorption. (1) The propeller is horizontally mounted on roller bearings to freely rotate in the direct path of the incoming stream. (2) A counter balanced swing action valve, located immediately behind the propeller, pivots upward to full open position where it offers negligible resistance to the flow. In all sizes propeller cage and valve orifice diameters are at least equal to actual pipe size. Accordingly, large volume flows are handled with dispatch and without change of direction of the flow. Turbulence is also overcome. This meter operates quietly.

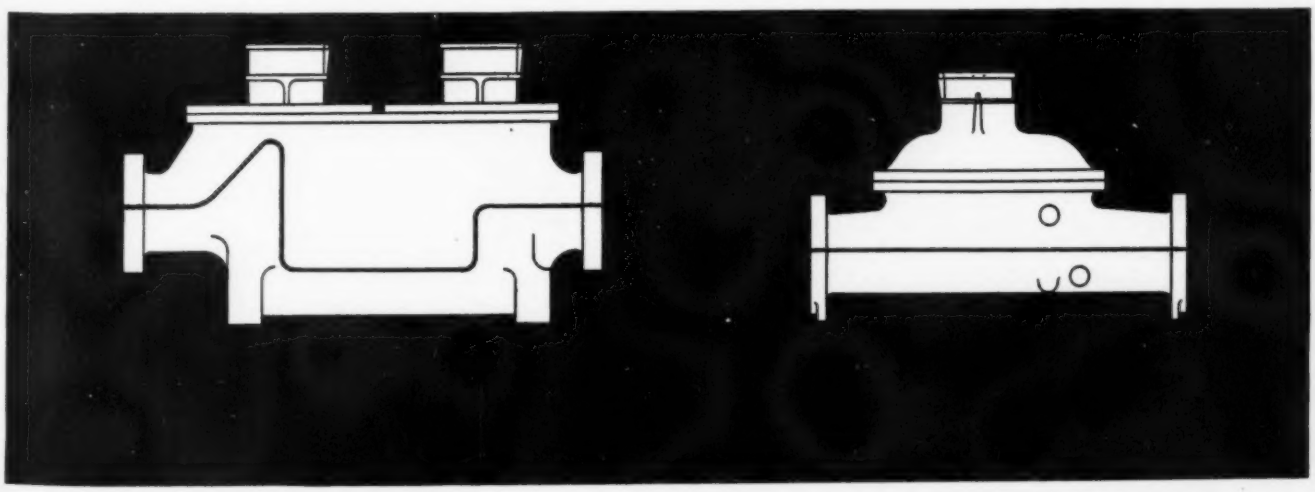
Now is a good time to check all the features of the lightweight, compact, single register Pittsburgh-Empire Compound. To get the full facts write your nearest sales office for a copy of bulletin W-803.

ROCKWELL

PITTSBURGH EQUITABLE METER DIVISION

Rockwell Manufacturing Company, Pittsburgh 8, Pa.

Atlanta Boston Chicago Houston Kansas City Los Angeles
New York Pittsburgh San Francisco Seattle Tulsa



Unit Responsibility

KEY TO MORE

. . . FROM INFLUENT TO EFFLUENT . . . IN PLANTS OF ANY SIZE

Regardless of the size or capacity of your plant, you can rely on Westinghouse for help in stepping up system efficiency. For Westinghouse produces dependable, installation-proved electrical equipment for co-ordinated drive and control of every process from influent to treated effluent.

Whether the drive requires ¼ hp or 5,000—50 motors or 500—Westinghouse can help you select and apply the right motor drive and control or any allied electrical equipment needed to improve your methods. Because Westinghouse can supply *all* of your electrical requirements, the expense and annoyance of piecemeal ordering are eliminated.

So today, as you plan modernization or extension of facilities, look to Westinghouse for the best in drive and control equipment regardless of the extent or nature of your needs. One supplier . . . one responsibility . . . one desired result: more efficient operation of every process from influent to effluent. Make Westinghouse your electrical partner at the planning board. For details call your Westinghouse office or write to Westinghouse Electric Corporation, P. O. Box 868, Pittsburgh 30, Pa. J-94747

OPERATING EFFICIENCY

"WESTINGHOUSE-EQUIPPED THROUGHOUT" MEANS SIMPLIFIED ORDERING, QUICKER INSTALLATION, MORE EFFICIENT OPERATION

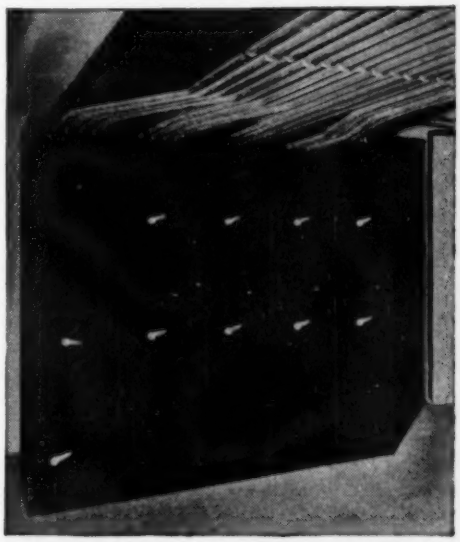
Putting power to work *productively* can be a major problem—or a simple one. When items must be selected, ordered and received from many sources, it means many chances for costly errors and delays . . . divided responsibility—or none at all—for performance of installed equipment.

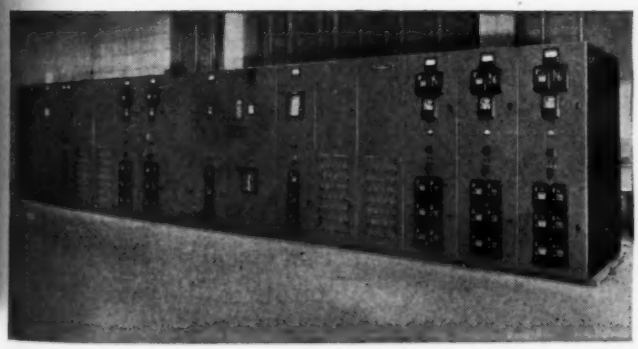
Westinghouse offers the way to simplify the job. From equipment for generation of electrical or steam power, to the most specialized types of drives and control for its utilization, Westinghouse provides a single source of supply . . . one broad pair of shoulders competent to take responsibility for performance of all parts of the job.

Here are a few of the places where Westinghouse unit responsibility prevents headaches . . . saves money . . . assures *more productive* power:

PANELBOARDS—Westinghouse control panelboard installed in a 9,000 gpm plant, including main incoming breaker, motor feeder breakers, lighting and auxiliary circuits; all in one attractive, easily installed unit.

CONTROL CENTERS—Typical Westinghouse Control Center which houses control for auxiliary motors at one centralized location—improves operating safety, simplifies operation and maintenance. Additional units can be added as needed.





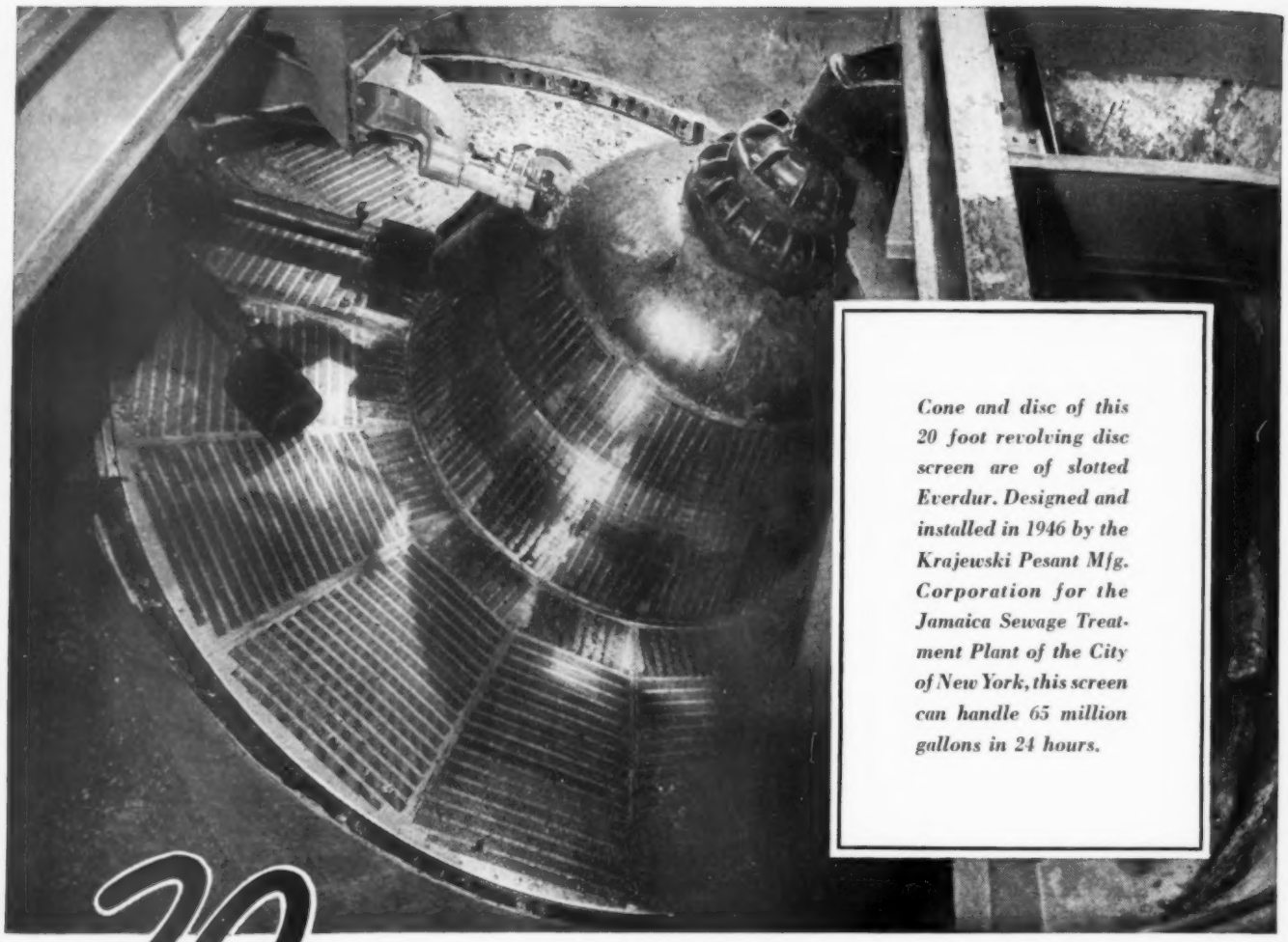
SWITCHGEAR—Westinghouse Indoor Metal-clad Switchgear (2,300 volts) for feeder circuits to main pump motors. Factory assembled and tested to assure proper protection of vital equipment. Installed as a unit.

MOTORS—One 350/160 and one 250/100 hp two-speed Westinghouse CS Motors driving main sewage disposal pumps. (Metal-clad control panel in background.) These motors use low speed and low hp for normal sewage flow. High speed and high hp increase pumping capacity 300 percent for handling emergency conditions.

Westinghouse

PLANTS IN 25 CITIES . . . OFFICES EVERYWHERE

MORE PRODUCTIVE POWER FOR INDUSTRY



Cone and disc of this 20 foot revolving disc screen are of slotted Everdur. Designed and installed in 1946 by the Krajewski Pesant Mfg. Corporation for the Jamaica Sewage Treatment Plant of the City of New York, this screen can handle 65 million gallons in 24 hours.

20 YEARS OF SEWAGE TREATMENT SERVICE PROVE *Everdur* SUPERIORITY

EVERDUR* copper-silicon alloys have achieved a consistent record for outstanding service and long life in hundreds of sewage and water works installations . . . over a period of twenty years.

Everdur alloys are notable for excellent corrosion resistance and great strength. Depending on the type or composition, they may be worked hot or cold, have good machining properties and are readily formed, forged and welded in producing lightweight built-up equipment of exceptional durability. Everdur equipment installed in 1927 is still in service and in excellent condition after constant use under highly corrosive conditions.

For detailed information write for Publications E-11 and E-5. 47187

*Reg. U. S. Pat. Off.

ANACONDA
from mine to consumer

Everdur

COPPER-SILICON ALLOYS

THE AMERICAN BRASS COMPANY

General Offices: Waterbury 88, Connecticut

Subsidiary of Anaconda Copper Mining Company

In Canada: ANACONDA AMERICAN BRASS LTD.
New Toronto, Ont.

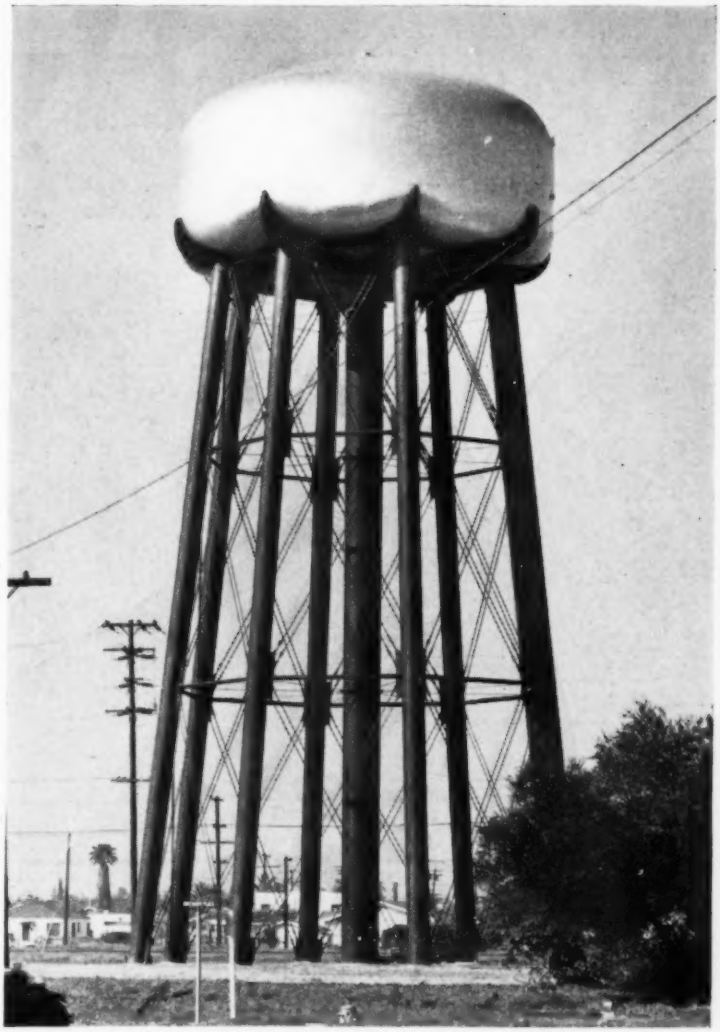
NEW 500,000-GALLON

HORTON ELEVATED TANK

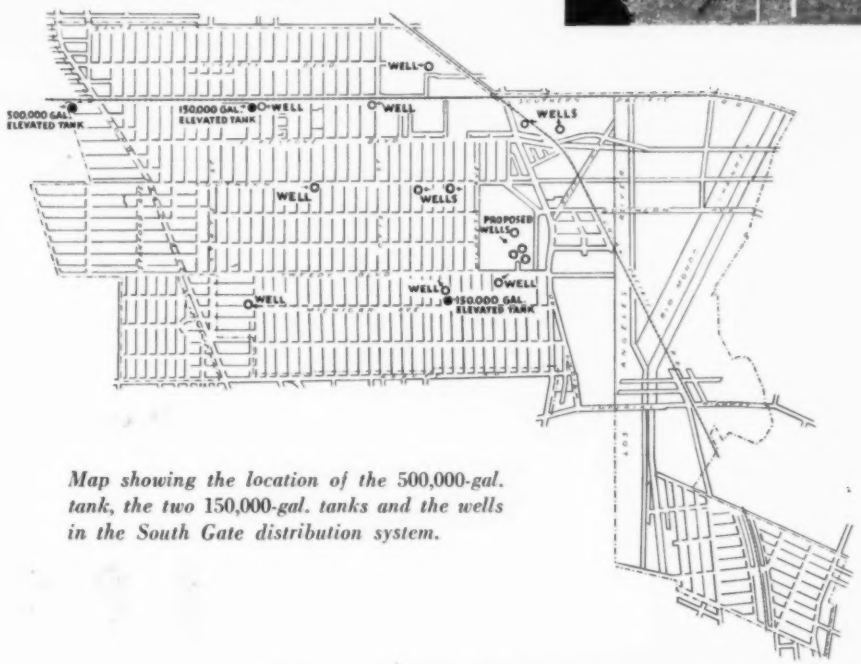
AT SOUTH GATE, CALIFORNIA

The Horton radial-cone bottom tank shown at the right was recently erected at South Gate to supplement two 150,000-gal. elevated tanks. The city's distribution system serves approximately 12,000 domestic and industrial customers. Water is obtained from wells and is pumped into the system by 14 electrically-driven pumps varying in capacity from 520 gpm to 2,300 gpm. Average daily consumption is 6,198,600 gals. with a maximum and minimum daily consumption of 8,912,000 gals. and 3,820,000 gals. respectively. There are 705 fire hydrants in the water system. It is not necessary to raise pumping pressure for serious fires. The new elevated tank and the installation of additional mains is expected to improve the insurance rating of the city.

Many water works engineers consider the installation of elevated storage as the most important step in improving and modernizing a municipal water supply system. More uniform water pressure, lower pumping costs and a more dependable supply of water for fire protection . . . are some of the benefits of elevated storage.



The above photo shows the 500,000-gal. Horton radial-cone bottom tank at South Gate, Calif. It is 112 ft. 9 in. to bottom. The double rods and sloped cylindrical columns were especially designed for this installation.



Map showing the location of the 500,000-gal. tank, the two 150,000-gal. tanks and the wells in the South Gate distribution system.

You are invited to write our nearest office for quotations on Horton elevated tanks when planning new water distribution systems or extensions to existing systems.

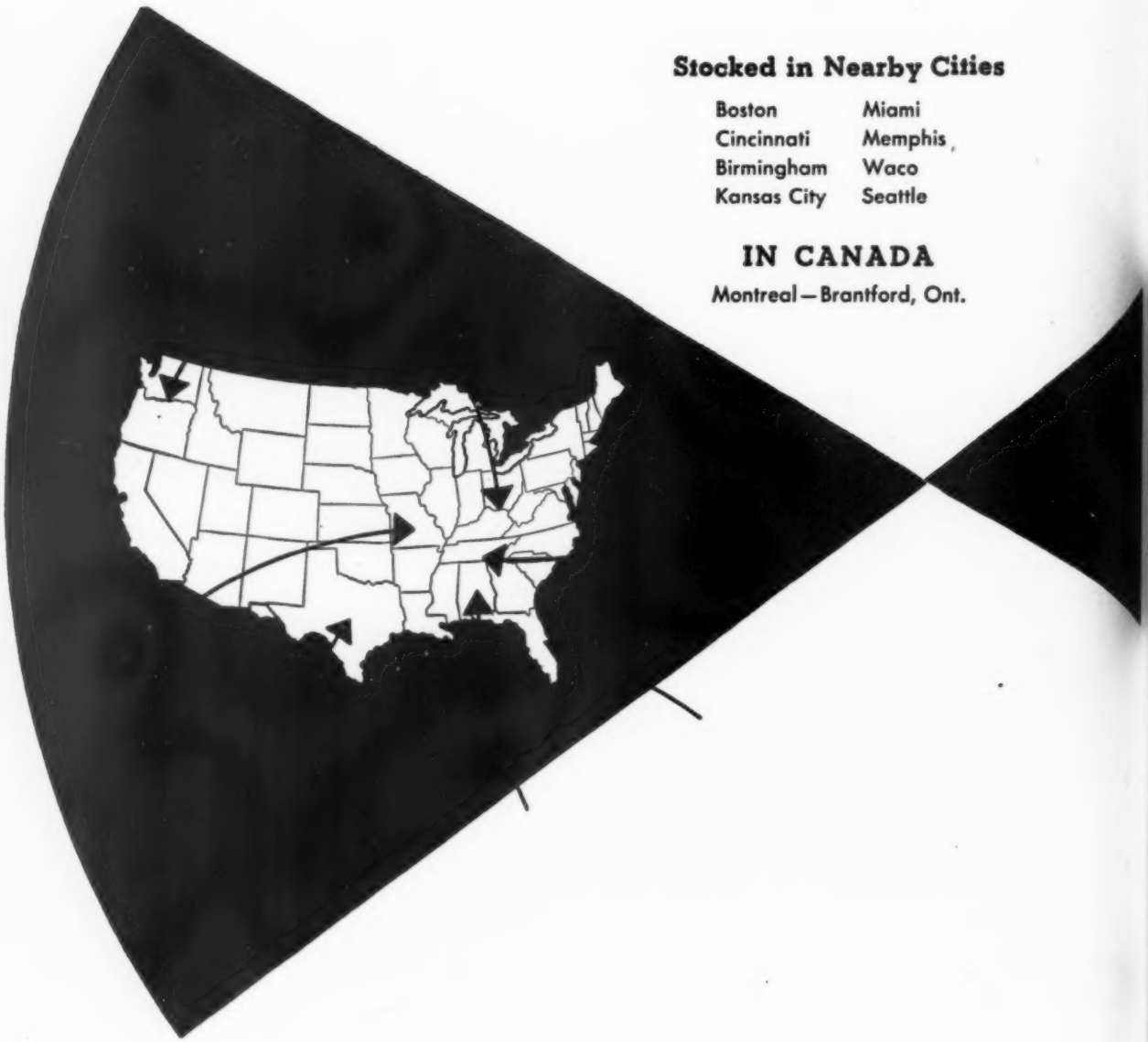
CHICAGO BRIDGE & IRON COMPANY

Chicago 4.....2198 McCormick Bldg.
New York 6.....3390-165 Broadway Bldg.
Cleveland 15.....2262 Guildhall Bldg.
Los Angeles 14.....1455 Wm. Fox Bldg.
Birmingham 1.....1586 North 50th St.
Atlanta 3.....2181 Healey Bldg.
Plants in Birmingham, Chicago and Greenville, Pa.

Tulsa 3.....1646 Hunt Bldg.
Houston 1.....5615 Clinton Dr.
Philadelphia 3.....1644-1700 Walnut Street Bldg.
Havana.....402 Abreu Bldg.
San Francisco 11.....1283-22 Battery Street Bldg.
Detroit 26.....1551 Lafayette Bldg.
In Canada: Horton Steel Works, Limited, Fort Erie, Ont.

Hydro-tite

ON HAND FOR WATER MAINS



Stocked in Nearby Cities

Boston	Miami
Cincinnati	Memphis
Birmingham	Waco
Kansas City	Seattle

IN CANADA

Montreal—Brantford, Ont.

HYDRAULIC DEVELOPMENT CORPORATION

EVERYWHERE

10 Reasons for Using

TIME-TESTED—*Hydro-tite* is as permanent as the pipe itself.

STRENGTH—Joints made with *Hydro-tite* will stand any pressure the pipe will stand.

LEAKAGE — *Hydro-tite joints* are tight.

FLEXIBILITY — Lines laid with *Hydro-tite* will stand severe deflection and vibration without leakage.

SHIPMENTS — Every order is given careful attention and shipment promptly made.

EASY TO USE—Ordinary workmen can make joints that are tight from the start.

SAVINGS IN MATERIAL-One pound of *Hydro-tite* is equal to four pounds of lead.

SAVINGS IN LABOR—*Hydro-tite* requires *NO CAULKING* and bell holes only large enough for yarning.

UNIFORMITY—Every bag of *Hydro-tite* is the same.

SERVICE—Assistance in making any kind of a test or demonstration desired is gladly furnished without charge. Send for sample.

HYDRO-TITE

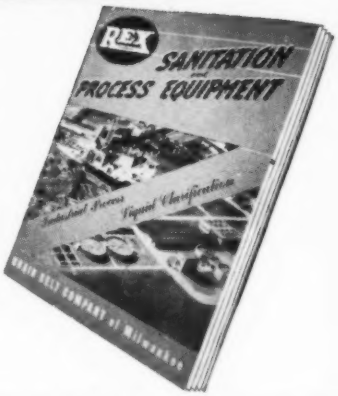
FIBREX

The sanitary, bacteria-repellent paper packing that is used like braided jute. Seventy pounds of FIBREX take the place of one hundred pounds of braided jute with proportionate savings in cost. Send for sample.

Main Sales Office: 50 Church Street, New York 7, N. Y.

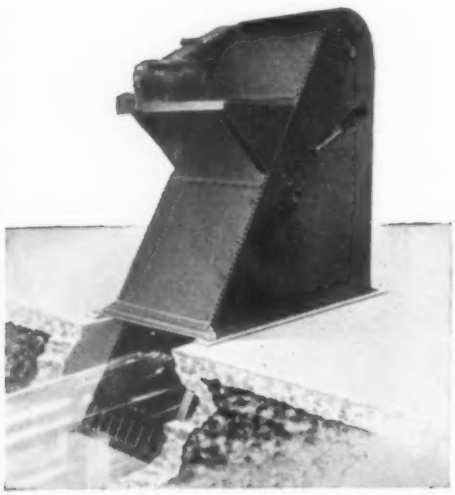
LARGE PLANT OR SMALL...

Rex Provides PROVED Equipment!

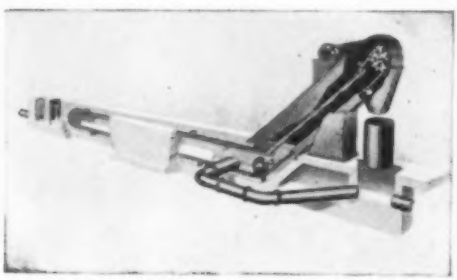


Large plant or small . . . primary or complete treatment . . . domestic or industrial waste, Rex provides the *right* equipment for every liquid clarification or solid separation operation.

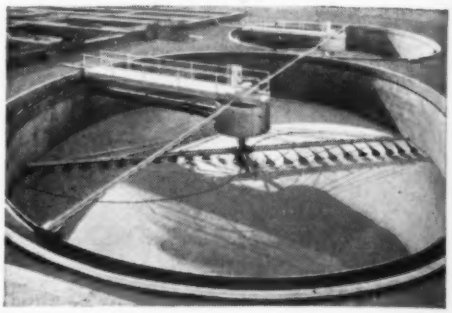
Small plants can obtain equipment that is equally efficient, equally economical and as durable as that for large plants. All Rex equipment and processes are time-tested and proved in hundreds of successful installations. Specially trained Rex sanitation engineers will be glad to help you with your problems. For facts write for your copy of Bulletin No. 46-3. Chain Belt Company, 1610 West Bruce Street, Milwaukee 4, Wisconsin.



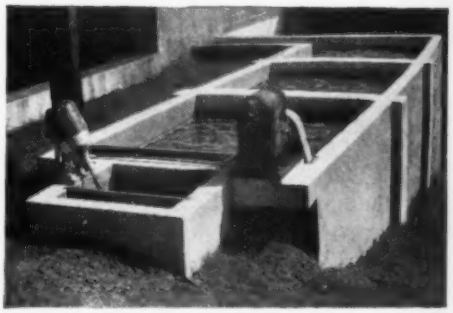
REX MECHANICALLY CLEANED BAR SCREENS are neat in appearance and provide an efficient means of removing large solids from liquids. They are easily installed in new or existing channels and have remarkably low head loss. With side frames recessed in channel walls, they assure an unobstructed flow to the rack.



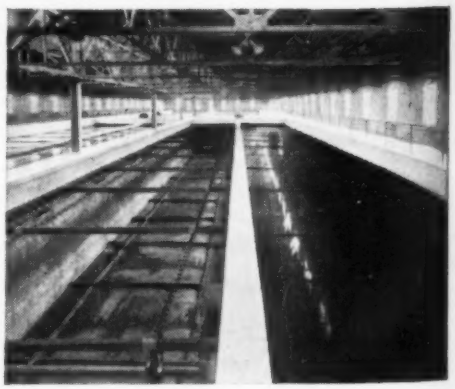
REX TOW-BRO SLUDGE REMOVERS are the only sludge collectors which remove sludge from tank bottom immediately on contact instead of by the usual blowing or scraping. They assure accurate control of sludge removal over a wide range of withdrawal rates. Greater sludge concentration, greater operating flexibility and a clearer effluent are all readily obtainable with Tow-Bro. ▶



REX FLASH MIXERS AND FLOCTROLS provide the necessary rapid dispersement of chemical throughout the liquid, followed by a gently multi-stage slow mixing for optimum floc formation. Floctrol designs assure utilization of full tank volume and important savings in chemicals. ▶



REX CONVEYOR SLUDGE COLLECTORS combine the well-known advantages of the rectangular settling tank with a rugged and efficient form of sludge removal mechanism. Whether handling primary sludge or light flocculent solids, their performance is trouble free and dependable. They rarely need to operate more than a few hours daily. ▶

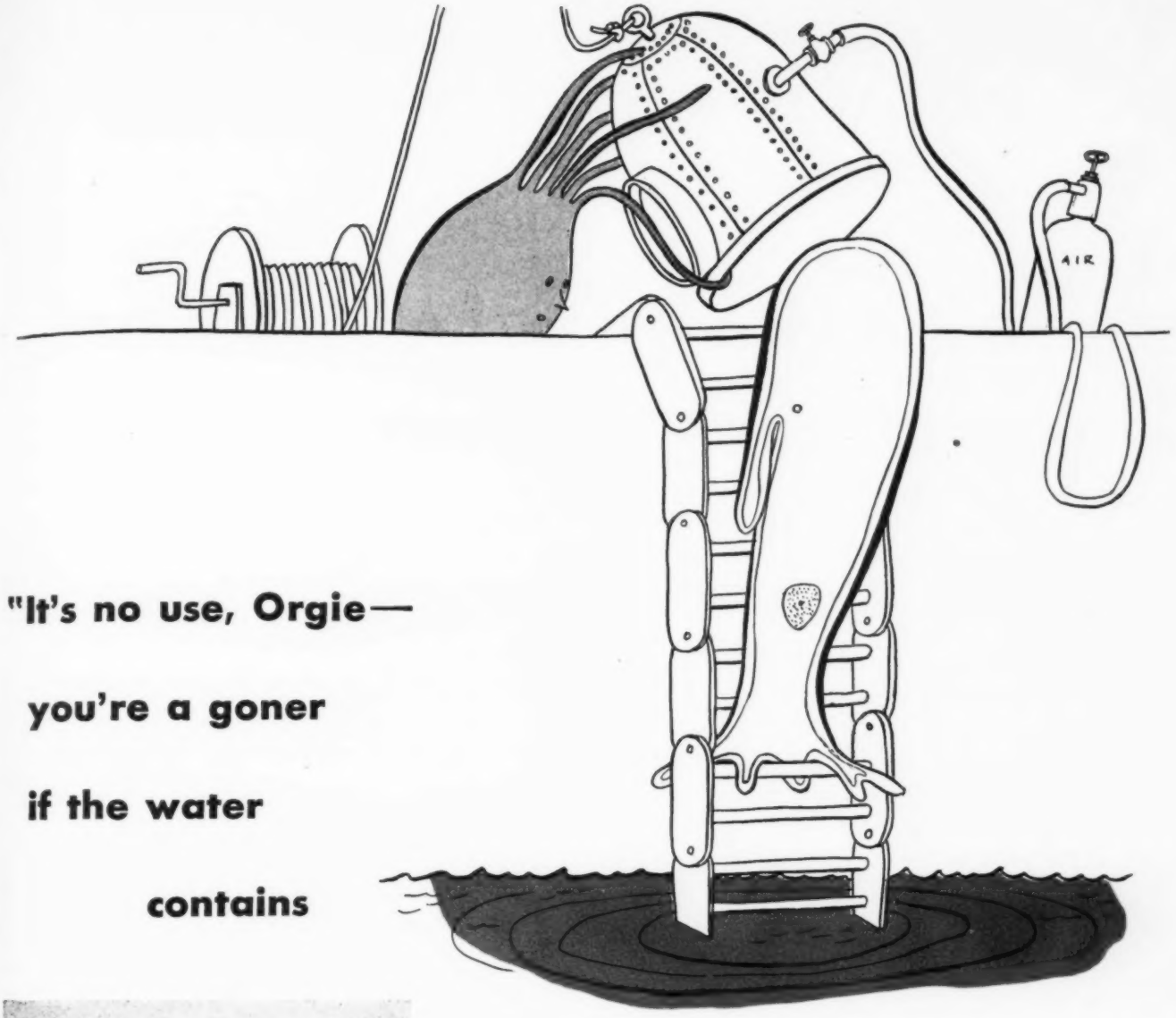


REX GRIT EQUIPMENT, incorporating the exclusive principle of recirculation, effectively separates and removes inorganic solids from liquids. No grit washer is needed. Long life is assured with minimum maintenance. ◀

REX SANITATION EQUIPMENT

Member of the Water and Sewage Works Manufacturers Association

CHAIN BELT COMPANY of Milwaukee



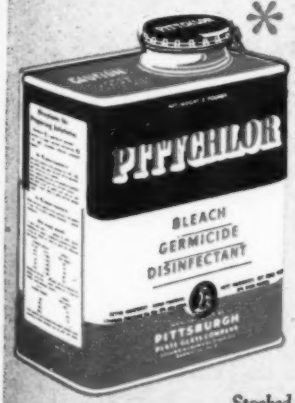
"It's no use, Orgie—

you're a goner

if the water

contains

*PITTCHLOR"



Stocked by leading jobbers in 5 lb. resealable cans (9 per case), 33¼ lb. cans (12 per case) and 130 lb. drums. Write for descriptive literature covering the uses in which you are interested.

COLUMBIA ESSENTIAL INDUSTRIAL CHEMICALS

Soda Ash · Caustic Soda · Liquid Chlorine · Sodium Bicarbonate Pittchlor and Pittcide (*Calcium Hypochlorites*) · Silene EF (*Hydrated Calcium Silicate*) · Calcium Chloride · Soda Briquettes (*Iron Desulphurizer*) · Modified Sodas · Caustic Ash · Phosflake (*Boiler Washer*) : Calcene T (*Precipitated Calcium Carbonate*)

Correct, Algie! Chlorine-susceptible microorganisms can acquire no immunity to the deadly effects of Pittchlor. Its 70% available chlorine is certain to exterminate most harmful families of bacteria and algae as soon as they are exposed to it. A high-test calcium hypochlorite, it is excellent for either local or general uses in the chlorination of water supplies, the treatment of sewage . . . and for many other disinfecting, deodorizing and general sanitation purposes.

**Trade Mark Reg. U. S. Pat. Off.*

COLUMBIA CHEMICALS

PITTSBURGH PLATE GLASS COMPANY

COLUMBIA CHEMICAL DIVISION

FIFTH AVE. at BELLEFIELD — PITTSBURGH 13, PENNA.

CHICAGO • BOSTON • PITTSBURGH — CLEVELAND • NEW YORK • CINCINNATI

ST. LOUIS • MINNEAPOLIS • CHARLOTTE — PHILADELPHIA • SAN FRANCISCO

DE LAVAL
Compressors for Sewage Plant Service

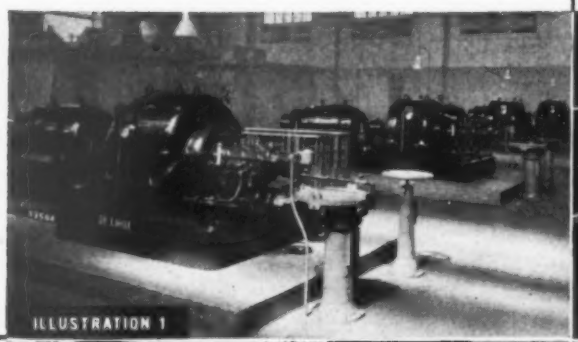


ILLUSTRATION 1

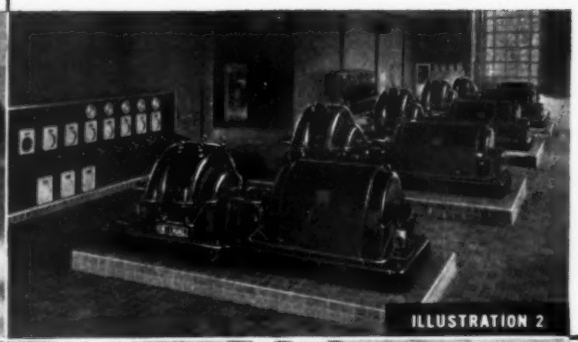


ILLUSTRATION 2

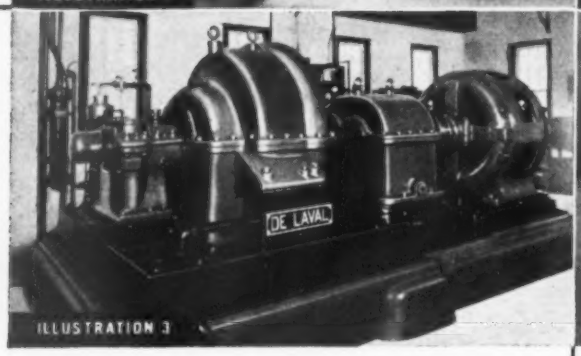


ILLUSTRATION 3

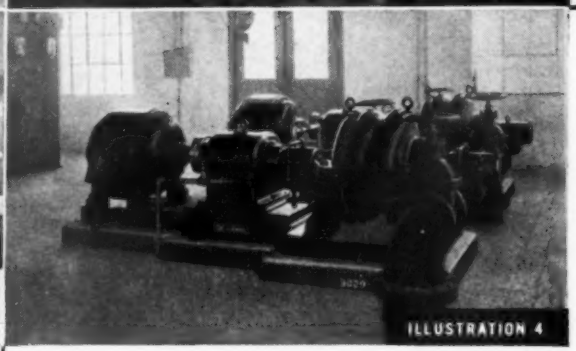


ILLUSTRATION 4

1. **De Laval Compressors of 10,000 CFM Capacity at 7 PSI** installed at the Bowery Bay Sewage Treatment Plant, New York, N. Y.

2. **De Laval Compressors at Cleveland.** Two are rated at 40,000 cfm against 7.4 lb. gage at 3560 rpm and two at 25,000 cfm.

3. **Two-Stage Compressor** in activated sludge disposal plant at Houston, Texas. This unit has been in service for more than 19 years, operating 99% of the time.

4. **Two De Laval Geared Turbine Compressors** supplying 3000 cfm each at 8 psi for sewage aeration.

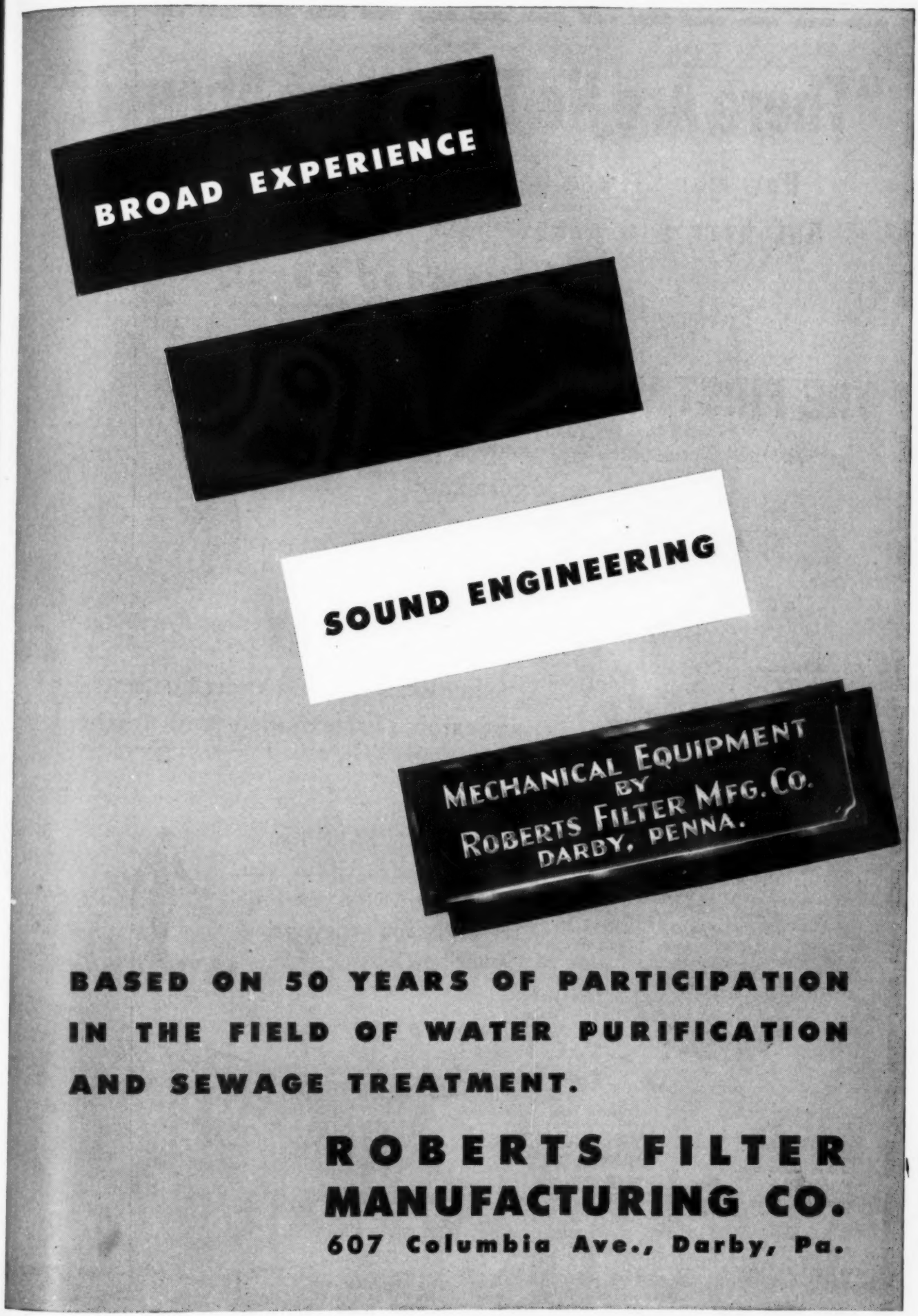
May we give you the benefit of our experience in figuring your compressor requirements?

Atlanta • Boston • Charlotte • Chicago • Cleveland • Denver
Detroit • Edmonton • Helena • Houston • Kansas City • Los Angeles
New Orleans • New York • Philadelphia • Pittsburgh • Rochester
St. Paul • Salt Lake City • San Francisco • Seattle • Toronto
Tulsa • Vancouver • Washington, D. C. • Winnipeg

DE LAVAL STEAM TURBINE CO.
TRENTON 2, N. J.
C-3

TURBINES • HELICAL GEARS • WORM GEAR SPEED REDUCERS • CENTRIFUGAL PUMPS • CENTRIFUGAL BLOWERS AND COMPRESSORS • IMO OIL PUMPS

AT THE CONVENTION VISIT DE LAVAL BOOTHS #43 AND 44.



BASED ON 50 YEARS OF PARTICIPATION IN THE FIELD OF WATER PURIFICATION AND SEWAGE TREATMENT.

ROBERTS FILTER MANUFACTURING CO.

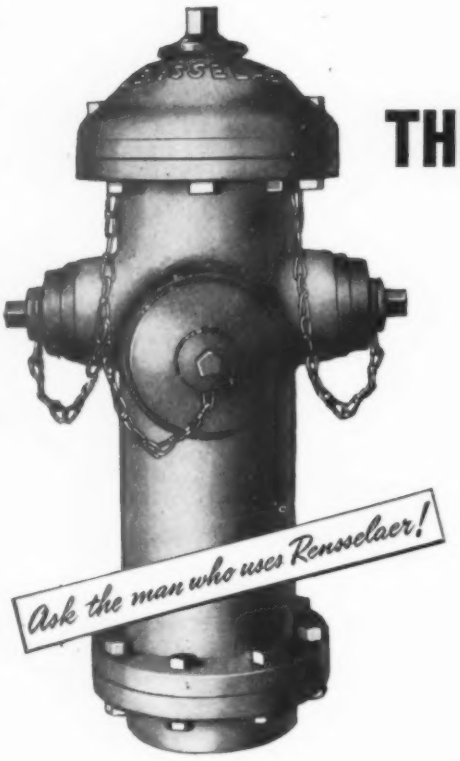
607 Columbia Ave., Darby, Pa.

"There Are No Two Ways About It"

How many times have you heard this phrase?
But here's a case where there are two ways
. . . and two good ways!

THE FIRST WAY

Install Rensselaer gate valves to assure years of trouble-free performance.



THE SECOND WAY

Install Rensselaer Defender hydrants for superior performance and faithful service.

Experienced Field Representatives bring to you RENSSELAER'S years of research and engineering "know-how".

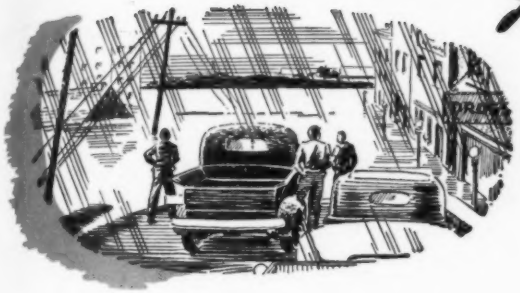
ATLANTA, GA.
333 Candler Bldg.
BALA-CYNWYD, PA.
725 Kenmare Road.
CHICAGO, ILL.
53 West Jackson Blvd.
DENVER, COLO.
P. O. Box 5270
HAVERHILL, MASS.
Haverhill National Bank Bldg.
HORNELL, N. Y.
38 Main St.
KANSAS CITY, MO.
1609 Oak St.
LOS ANGELES, CALIF.
Subway Terminal Bldg.
MEMPHIS, TENN.
822 Dermon Bldg.
MINNEAPOLIS, MINN.
625 Plymouth Bldg.
OKLAHOMA CITY, OKLA.
817 Braniff Bldg.
PITTSBURGH, PA.
2203 Oliver Bldg.
SAN FRANCISCO, CALIF.
115 Townsend St.
SEATTLE, WASH.
1252 First Ave., South
WACO, TEXAS
206 Franklin Ave.

RENSSELAER VALVE CO.

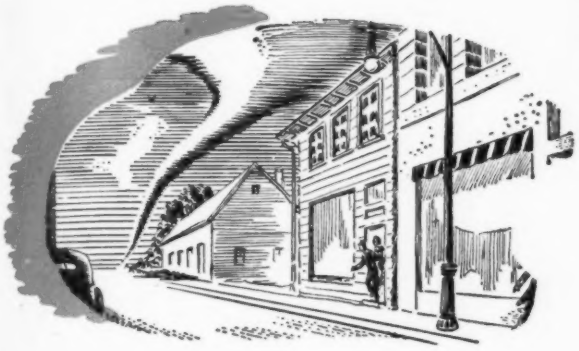
TROY, N. Y.

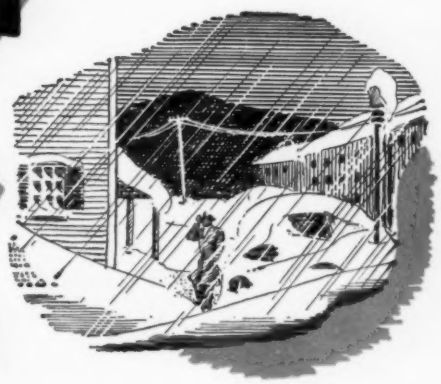
Are you prepared

FOR THE BIG



"IF"





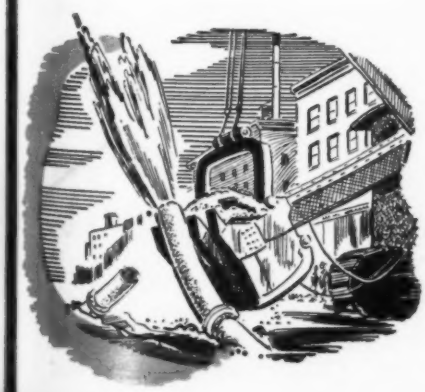
The possibility of explosion, flood, tornado, blizzard, many other emergencies constantly threatens the flow of safe water. That's why so many smart engineers maintain a supply of Per*chlor*on as a standby water treatment chemical. They know that Per*chlor*on has proved itself in every section of the country, by quickly and dependably safeguarding water supplies in a wide variety of emergencies.

Per*chlor*on serves other water treatment functions, too . . . sanitation of small water systems, new mains, wells, swimming pools. Its properties include the oxidation of ferrous iron in water, removal of hydrogen sulphide, control of most types of algae, and the destruction of chlorine-susceptible bacteria. Write us for full descriptive material.

PENNSYLVANIA SALT MANUFACTURING COMPANY

1000 Widener Building, Philadelphia 7, Pa.

NEW YORK • CHICAGO • ST. LOUIS • PITTSBURGH • CINCINNATI
WYANDOTTE • TACOMA • PORTLAND, ORE.

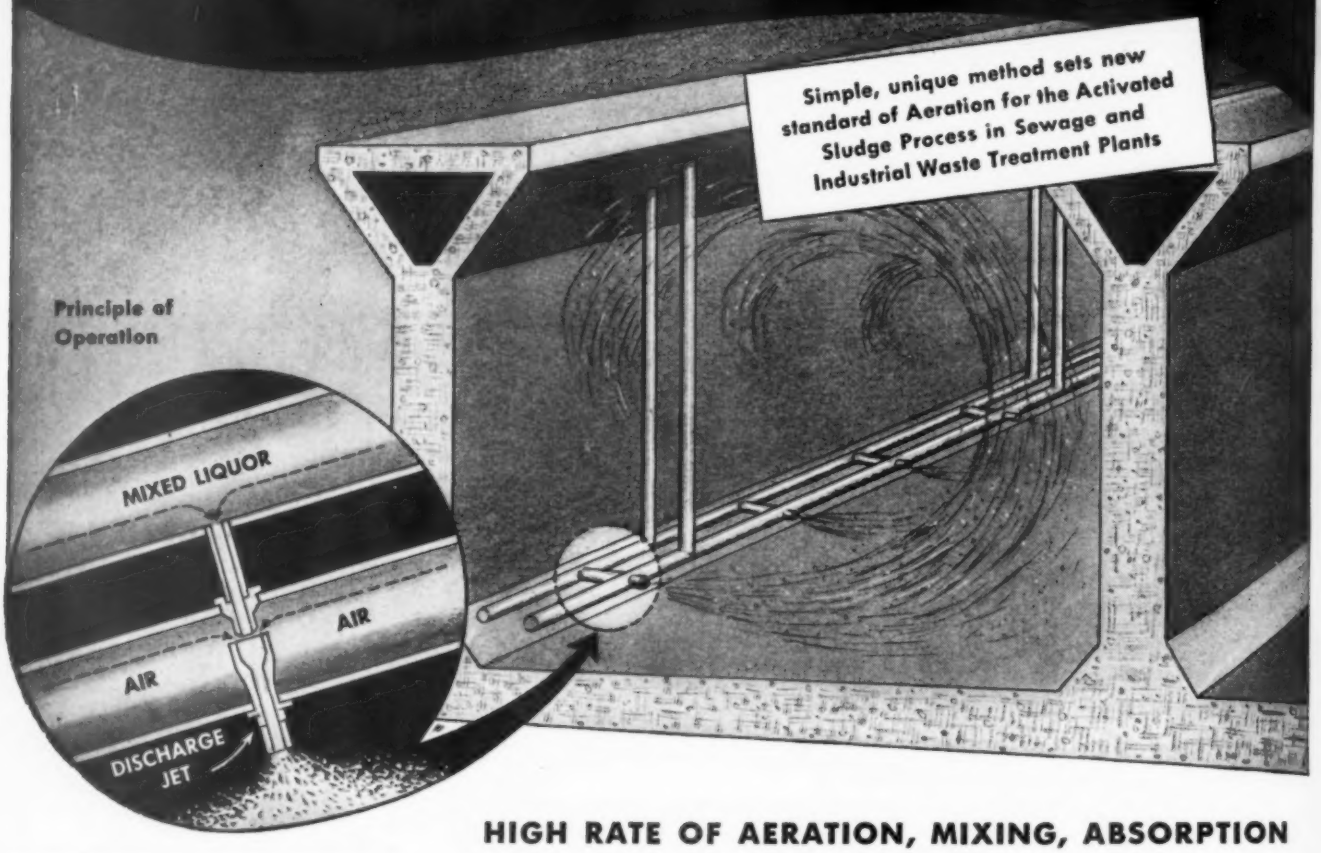


PENN SALT

Perchloron

REG. U. S. PAT. OFF.

5 Times more Oxygen Absorption AT LESS COST... with American Jet Aeration


Simple, unique method sets new standard of Aeration for the Activated Sludge Process in Sewage and Industrial Waste Treatment Plants
Principle of Operation
MIXED LIQUOR
AIR
AIR
DISCHARGE JET

HIGH RATE OF AERATION, MIXING, ABSORPTION

This original type of aerating process combines mixed liquor with air, under jet pressure, by an exclusive method that produces an unprecedented high rate of oxygen absorption.

Pumped into a header at a pressure of 15 to 25 lbs. per square inch, the mixed liquor jets through an air header, entraining compressed air. The force of this homogeneous jet of finely divided air and liquor, *traveling in the same direction,* creates a mixing motion which insures intimate contact between activated sludge floc, the widely dispersed particles of air, and organic matter in the tank contents.

This provides an ideal condition for a high rate of oxygen absorption. *No other method of aeration achieves this condition as completely or at the same low cost.*

In actual installations of this type of jet aeration, oxygen absorption has been measured at 20 per cent, or five times more than with the usual diffusion plates or tubes.

Write for full information on the application of American Jet Aeration to your special conditions.

In addition to higher oxygen absorption, you get THESE FEATURES:

- No clogging—No cleaning
- No accumulative back pressure on blowers
- Lower power consumption
- Simple and inexpensive installation
- No air filters or liquid strainers
- Greater flexibility of application and operation

Additional aeration readily provided for existing plants. Present diffuser plate or tube installations easily modified for Jet Aeration.

Our staff of Sanitary Engineers will cooperate with consulting and operating engineers in suggesting the process of treatment and type of equipment best suited to individual needs.

Licensed by The Dow Chemical Company

AMERICAN WELL WORKS

IN OUR 79TH YEAR
102 North Broadway
AURORA, ILLINOIS

Pumping, Sewage Treatment, and Water Purification Equipment
RESEARCH • ENGINEERING • MANUFACTURING

Offices: Chicago • New York • Cleveland • Cincinnati • Kansas City • Sales Representatives throughout the World

Davey Valves Assure PERMANENT PEAK EFFICIENCY

Any compressor will run perfectly when it is new... and will produce its rated air capacity.

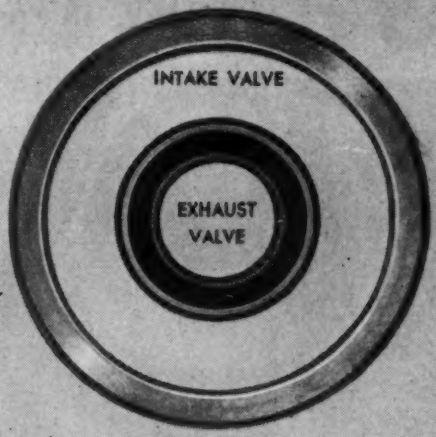
The real test of quality comes with increasing age... the manner in which a unit operates after 5-10-15 years of service. This depends 100% on valve efficiency.

In Davey Compressors permanent peak valve efficiency is the result of providing a ready path for heat removal through aluminum alloys. These alloys transmit heat through their mass three times as fast as cast iron.

Consequently, Davey units operate at constant peak efficiency—longer and more economically.

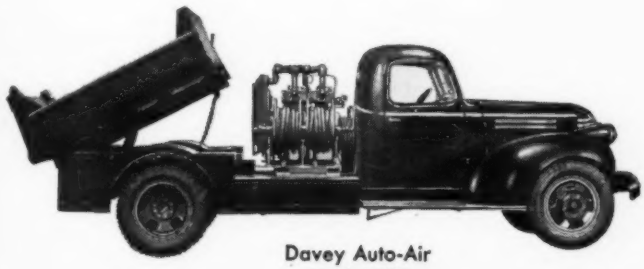
Davey is your best compressor investment—both for today and tomorrow. See your Davey dealer now. Ask him to tell you more about Davey valves—also, how vibration has been "engineered out" of the Davey line for '47.

P & P-115



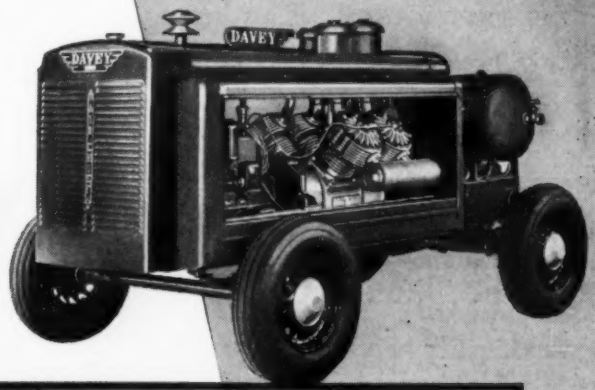
AFTER 13 YEARS of continuous service, these valves were recently removed from a Davey Compressor.* Their peak-efficiency condition is attested by the absence of carbon or pitting. Note how they have obviously seated perfectly—the complete absence of any signs of leakage . . . after 13 years.

**Owner's name on request.*



Davey Auto-Air
Model 105

Davey Air Chief
Model 210

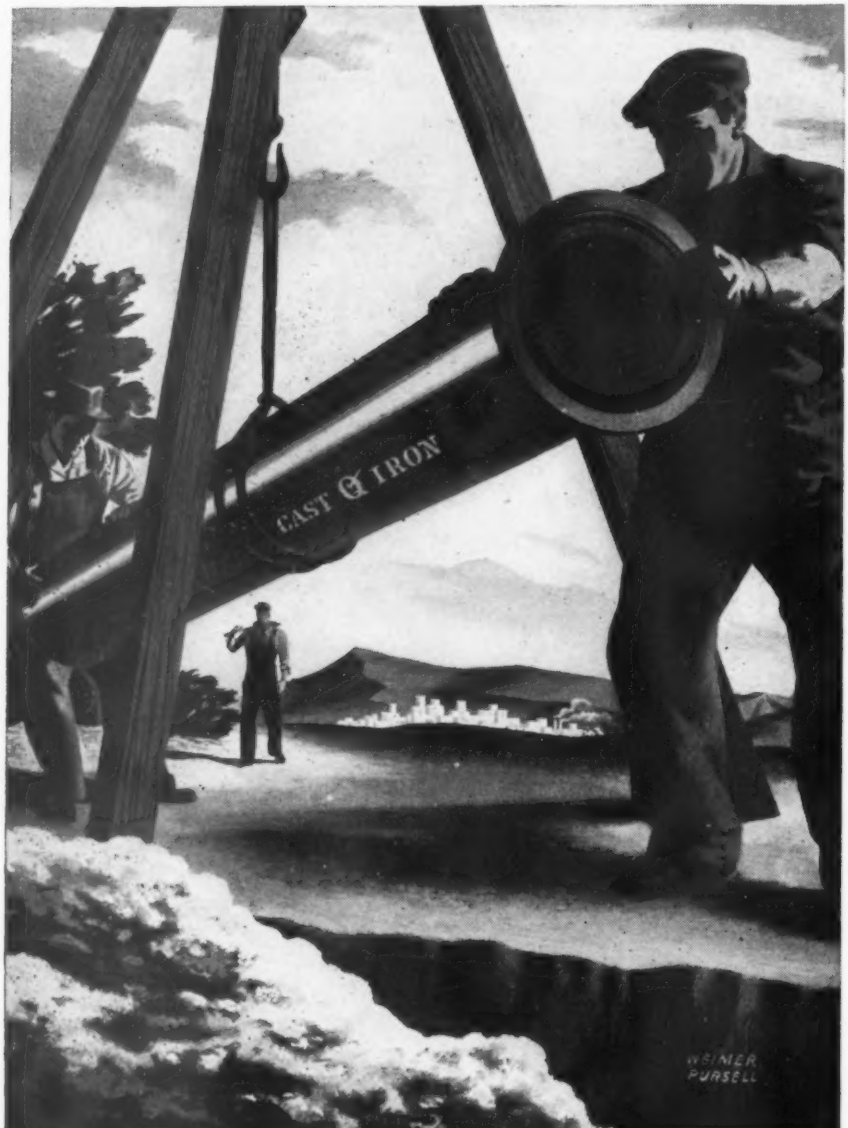


DAVEY

DAVEY COMPRESSOR CO.

KENT, OHIO

ITS "LIFE EXPECTANCY"



"LIFE EXPECTANCY" is an insurance term meaning how long the average man can be expected to live. There is an interesting parallel in the life expectancy of man and of cast iron pipe. For, in recent years, the "life expectancy" of both has been *steadily revised upward!*

The lengthened life of man is attributable to progress in dietetics, medicine, and the purity of water supply.

The estimated efficient life of cast iron pipe has been steadily revised upward because of service records.

In evaluating bids it is standard practise to estimate the efficient life of cast iron pipe at 100 years *minimum.* Consulting and water works engineers base this estimate on the known records of cast iron mains in this country which have been in service for more than 100 years. Moreover, they know that this century-old pipe was cast by methods that were primitive compared to the highly-developed production techniques of today.

Nobody knows for sure what the "life expectancy" of cast iron pipe may prove to be. The earliest authenticated installation of a cast iron water main is still functioning after nearly 300 years of service.

CAST IRON PIPE

IS STEADILY RISING

PIPE LINES

Other installations in Europe are entering their third century of service. It is on these service records that the Cast Iron Pipe Research Association bases its slogan, *"Serves for Centuries."*

"Cast iron pipe not only offers a century or more of efficient life as a structure—it offers a century or more of efficient life as a carrier. In the limited areas with tuberculating waters, cement-lined cast iron pipe is tuberculation-proof and insures high carrying capacity for the life of the pipe. In the greatly predominating areas without tuberculating waters, the carrying capacity of unlined cast iron pipe remains practically unimpaired for the life of the pipe."

Cast Iron Pipe Research Association, T. F. Wolfe, Research Engineer, Peoples Gas Bldg., Chicago 3.

New York's Underground Empire

Approximately two million lengths of pipe of which more than 95% is cast iron pipe, distribute water to the five boroughs of New York City—upwards of 5,000 miles of distribution mains which, if laid in a straight line, would reach from New York to San Francisco and nearly half way back again—this is New York's "underground empire." These mains distribute more than 900,000,000 gallons of water per day. Some sources of supply are more than 100 miles distant.

A Billion Gallons Per Day

Chicago, from an inexhaustible supply, pumps more than a billion gallons a day through her one-and-a-half million lengths of pipe, 99.9% of which is cast iron pipe. The rated pumping capacity of Chicago's system is 1,900,000,000 gallons a day.

Fifteen Largest Cities

Here are some more typical figures giving the percentage of cast iron pipe used in the water distribution systems of the 15 largest cities in the United States, as recently reported by their Water Departments: Philadelphia, 98.3%; Detroit, 98.7%; Cleveland, 98.9%; St. Louis, 98.7%; Boston, 99.8%; Pittsburgh, 97.9%.

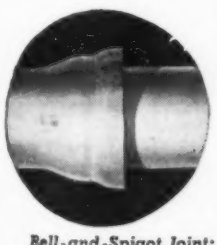
And In Treatment Plants

The wide acceptance of cast iron pipe is further evidenced by the fact that well over 95% of all the pipe in Water Filtration plants and Sewage Treatment plants, throughout the United States, is cast iron pipe. Under the ground, above ground, under water or set in concrete, cast iron pipe is the standard material.

Still Going Strong

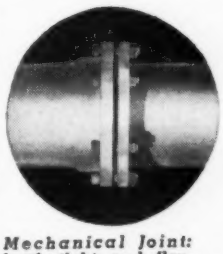
Original cast iron mains have in some instances been abandoned or salvaged when it became necessary to replace them with larger-sized cast iron pipe. Nevertheless, a recent survey shows that some or all of the original cast iron water mains are still in service in 200 out of 212 of America's large cities; impressive evidence of long life and economy.

Joints for Cast Iron Pipe



Bell-and-Spigot Joint: the standard joint for water and sewerage service.

A variety of joints are available, of which the two most widely used are illustrated. Special purpose joints, such as the Ball-and-Socket, or Flexible Joint for underwater use, and the Flanged Joint for above-ground use, are also available.



Mechanical Joint: bottle-tight and flexible, now with interchangeable parts.

SERVES FOR CENTURIES

Crane Valves do more than control flow

A SUBURBAN VILLAGE *waterworks equips with Crane. Shown are Crane 10-in. gear and chain wheel operated gate valves on high lift pumps.*

A. W. W. A. GATE VALVES BY CRANE *are assurance of complete compliance with newest specifications, and of the best valve performance in their class. Pattern No. 2495, illustrated, double disc, outside screw and yoke, flanged ends, comes in 2 to 24-in. sizes. See Crane Catalog supplement 3A, page 126.*

In water and sewage plants the country over, Crane valves do more than just stop and start flow. By doing that job precisely, they safeguard public health. By giving unusually long and faithful service, they hold valve maintenance, repair and replacement costs to the lowest level.

To the men responsible for public water services, Crane valves assure peace of mind under all working conditions. Wouldn't you feel safer with valves and fittings having a reputation for dependability through more than 90 years?

CRANE CO., General Offices: 836 S. Michigan Avenue, Chicago 5, Illinois. *Nationwide Service Through Branches and Wholesalers.*

A LARGE CITY *pumping station specifies Crane quality valves—gates, globes, angles, checks—from the smallest to the 36-in. motor-operated control valves to mains.*

VALVES · FITTINGS · PIPE

CRANE

PLUMBING AND HEATING

CHEMICAL USERS' GUIDE To General Chemical Company Products for Treatment of Water, Sewage, and Industrial Wastes

PRODUCT	AVAILABLE FORMS	COMMERCIAL STRENGTH (MIN.)	SHIPPING CONTAINERS	APPLICATIONS
Aluminum Sulfate $Al_2(SO_4)_3 \cdot 14H_2O$ approx. *(Filter Alum)*	Commercial & Iron Free: Lump • Ground Powdered	17.25% Al_2O_3	Bags Barrels • Drums Bulk Carloads	Coagulant for water and sewage. Dewatering conditioner for sewage sludge. 1% Sol. pH 3.4.
Aqua Ammonia NH_4OH plus Water *(Ammonia Water)*	Colorless Liquid	26°Be. (29.4% NH_3)	Steel Drums Carboys	Used with chlorine to form chloramines for water disinfection.
Ammonium Aluminum Sulfate $Al_2(SO_4)_3 \cdot (NH_4)_2SO_4 \cdot 24H_2O$ *(Ammonia Alum) (Crystal Alum)*	Lump Nut Granular Powdered	11.2% Al_2O_3	Bags Fibre Drums	Coagulant for water. Advantageous for pressure filters. Supplies ammonia for chloramine formation. 1% Sol. pH 3.5.
Sodium Bisulfite, Anhydrous $Na_2S_2O_5$ *(ABS) (Sodium Metabisulfite)*	Powdered	97.5% $Na_2S_2O_5$ (Equiv. 65.5% SO_2)	Fibre Drums	Antichlor. Remove iron and manganese deposits from filter sand. 1% Sol. pH 4.6.
Sodium Silicate $Na_2O \cdot X(SiO_2)$ plus H_2O *(Water Glass) (Silicate of Soda)*	Viscous Liquid	38° to 52°Be. Various Ratios of Na_2O:SiO_2	Drums Tank Cars Tank Trucks	1. Aid in floc formation. 2. Prevent red water corrosion in distribution lines. 1% Sol. pH 12.7
Sodium Thiosulfate $Na_2S_2O_3 \cdot 5H_2O$ *(Hypo) (Sodium Hyposulfite)*	Crystals: Prismatic Rice Selected Universal Granular	99.75% $Na_2S_2O_3 \cdot 5H_2O$	Bags Barrels Fibre Drums	Antichlor. Water solution is neutral.
Sulfuric Acid H_2SO_4 plus H_2O *(Oil of Vitriol)*	Corrosive, oily liquid Various strengths	66°Be. (93.19% H_2SO_4)	Bottles Carboys Drums Tank Trucks Tank Cars	1. Reduce pH and alkalinity. 2. Regenerate carbaceous zeolites and ion exchangers. 3. Activate Baylis Silicate.
Potassium Aluminum Sulfate $Al_2(SO_4)_3 \cdot K_2SO_4 \cdot 24H_2O$ *(Potash Alum)*	Lump Nut Granular Powdered	10.7% Al_2O_3	Bags Fibre Drums	Coagulant for water. Slow, even rate of solubility desirable for solution pot feeders. 1% Sol. pH 3.52.
Sodium Sulfite, Anhydrous Na_2SO_3 *("Sulfite")*	Granular Powdered	98.5% Na_2SO_3	Bags Fibre Drums	Antichlor, oxygen remover. Weak solutions absorb oxygen readily. 1% Sol. pH 9.8.
Sodium Sulfate, Crystal $Na_2SO_4 \cdot 10H_2O$ *(Glauber's Salt)*	Crystal & Needle Crystal	96% $Na_2SO_4 \cdot 10H_2O$	Barrels Bags Drums	Neutral Solution. Boiler water treatment (maintenance of sulfate-carbonate ratio).
Sodium Sulfate, Anhydrous Na_2SO_4	Powdered	99.5% Na_2SO_4	Bags Barrels	Neutral Solution. Boiler water treatment (sulfate-carbonate ratio)
Trisodium Phosphate $Na_3PO_4 \cdot 12H_2O$ *(TSP)*	Crystal	98.5—103% $Na_3PO_4 \cdot 12H_2O$ (Equiv. 19% P_2O_5)	Bags Barrels Fibre Drums	Boiler water treatment. Cleaning compound. 1% Sol. pH 11.8-12.0.
Disodium Phosphate, Crystal $Na_2HPO_4 \cdot 12H_2O$	Crystal	98% $Na_2HPO_4 \cdot 12H_2O$ (Equiv. 19.5% P_2O_5)	Bags Barrels Fibre Drums	Boiler water. (Calcium and magnesium precipitation.) 1% Sol. pH 8.4.
Disodium Phosphate, Anhydrous Na_2HPO_4	Powdered Flake	96% Na_2HPO_4 (Equiv. 48% P_2O_5)	Same	Same as Crystal, but stronger product.
Sodium Fluoride NaF *(Fluoride)*	Powdered (white or blue colored: Nile Blue) Light or dense	90% and 95% NaF	Bags Barrels Fibre Drums	Fluorination of water supplies. (For information, consult with local health officers.)

FOR THE LABORATORY: Baker & Adamson Laboratory Reagents

For full information on these and other General Chemical Company products, write or phone the nearest Sales and Technical Service Office below.

GENERAL CHEMICAL COMPANY

40 RECTOR STREET, NEW YORK 6, N. Y.

Sales and Technical Service Offices: Albany • Atlanta • Baltimore • Birmingham • Boston • Bridgeport Buffalo • Charlotte • Chicago • Cleveland • Denver • Detroit • Houston • Kansas City • Los Angeles Minneapolis • New York • Philadelphia • Pittsburgh • Providence • San Francisco • Seattle • St. Louis Wenatchee and Yakima (Wash.)

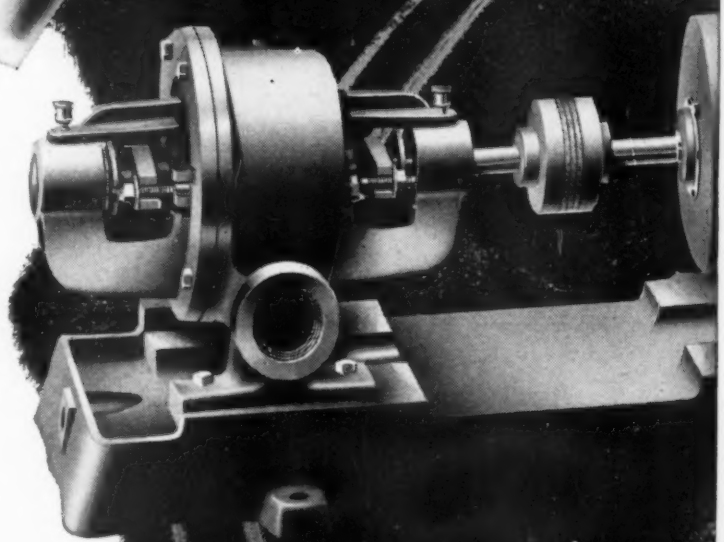
In Wisconsin: General Chemical Wisconsin Corporation, Milwaukee, Wis.

In Canada: The Nichols Chemical Company, Limited • Montreal • Toronto • Vancouver

HERE TODAY—STILL HERE TOMORROW!

There is a Fairbanks-Morse Centrifugal for all your pumping needs.

Fairbanks-Morse-Pomona deepwell turbine pumps. Oil or water lubricated; open or closed impellers—as your job requires.



Famous Westco turbine-type pumps have exclusive advantages for service involving small capacities, high heads and low speeds.

The values in doing business with one of the hundreds of well-established, progressive Fairbanks-Morse pump dealers are many:

First, of course, you gain immediate advantages from the intensive research, skilled productive techniques and well-developed service organization that have long been identified with the Fairbanks-Morse name.

Too, you gain the long-term advantages of continued aid in keeping your pumps on the job—continued benefits from the widespread, quickly available Fairbanks-Morse dealer organization.

For a pump that's to give high efficiency year after year, buy from the dealer who will stand by you, year after year. See your Fairbanks-Morse pump dealer for all your pumping requirements.

FAIRBANKS-MORSE

A name worth remembering

DIESEL LOCOMOTIVES • DIESEL ENGINES • PUMPS • SCALES • MOTORS • GENERATORS • STOKERS • RAILROAD MOTOR CARS and STANDPIPES • FARM EQUIPMENT • MAGNETOS

10 GOAL PERFORMANCE

INSURES PALATABLE DRINKING WATER
NUCHAR

In polo, a ten goal rating is the highest, only attained after years of active competition. In the water purification field, AQUA NUCHAR Activated Carbon has come to be known as "tops" after more than 15 years of pioneering development. That is why over 1,200 communities have used AQUA NUCHAR to insure tasteless, odorless water . . . at the incredibly low average cost of less than two cents per capita per year.

Besides having demonstrated its ability to remove tastes and odors from raw water supplies, AQUA NUCHAR is also effective as a dechlorinating medium and is utilized where prechlorination or super-chlorination is practiced. Now, by using chlorine for water sterilization, and AQUA NUCHAR to remove the subsequent objectional chlorine taste, it is possible to deliver a *palatable* as well as *safe* water to the consumers.

AQUA NUCHAR Activated Carbon is stocked in principal cities throughout the country . . . ready to serve you at a moments notice.

industrial
CHEMICAL SALES
division west virginia pulp and paper company

230 PARK AVENUE
NEW YORK 17, N. Y.

35 E. WACKER DRIVE
CHICAGO 1, ILLINOIS

748 PUBLIC LEDGER BLDG.
PHILADELPHIA 6, PA.

844 LEADER BLDG.
CLEVELAND 14, OHIO

SERVICISED CONSTRUCTION MATERIALS FOR SEWAGE TREATMENT WORKS

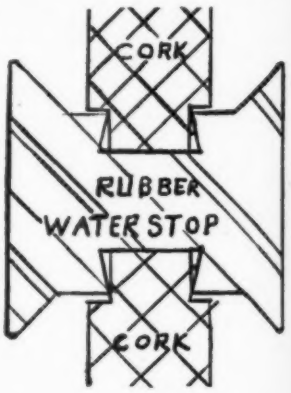
Panoramic View of Construction at Southwest Sewage Treatment Works

The Sanitary District of Chicago — The World's Largest Sanitation System is expanding its present Southwest Sewage Treatment Works to double its present size. This system serves some sixty cities and villages in Cook County in addition to the city of Chicago.

Supervising Engineers — Sanitary District Staff Engineers.
General Contractors—M. J. Boyle & Company.

In this huge expansion construction, SERVICISED Cork Expansion Joint conforming to Federal Specification HH-F-341, Type I, is being used. For top sealing these Cork Expansion Joints, Para-Plastic Rubberized Joint Sealing Compound conforming to Federal Specifications SS-F-336 is specified. Shown at the right is a typical concrete slab with SERVICISED Cork Expansion Joint. Yet to be Hot Poured is the Para-Plastic Sealing Compound to seal these joints water tight.

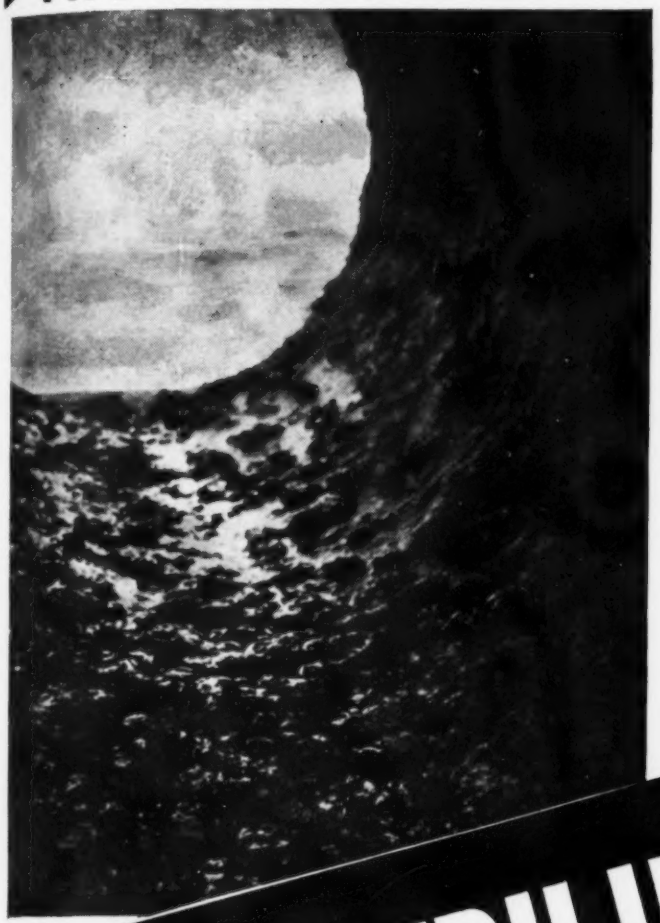
EXTENDAKOTE is a specialized usage designed by Servicised consisting of a steel plate coated with waterproofing Para-Plastic. Shown at the left is a specialized usage in the Southwest Sewage Treatment Works construction. Steel plates capped with Cork Expansion Joint are coated with Para Plastic Sealing Compound.



In the construction of Philadelphia's new Northeast Sewage Treatment Works, Servicised Self-Expanding Cork is used with Rubber Water Stops. Para-Plastic Sealing Compound is specified in this huge construction also. The diagram at the right shows the Self-Expanding Cork and Rubber Water Stop assembly as used in this construction.

SERVICISED PRODUCTS CORP.
6051 West 65th Street, Chicago 38, Ill.

▸ PIPE LINING FACTS NO. 1 ◂



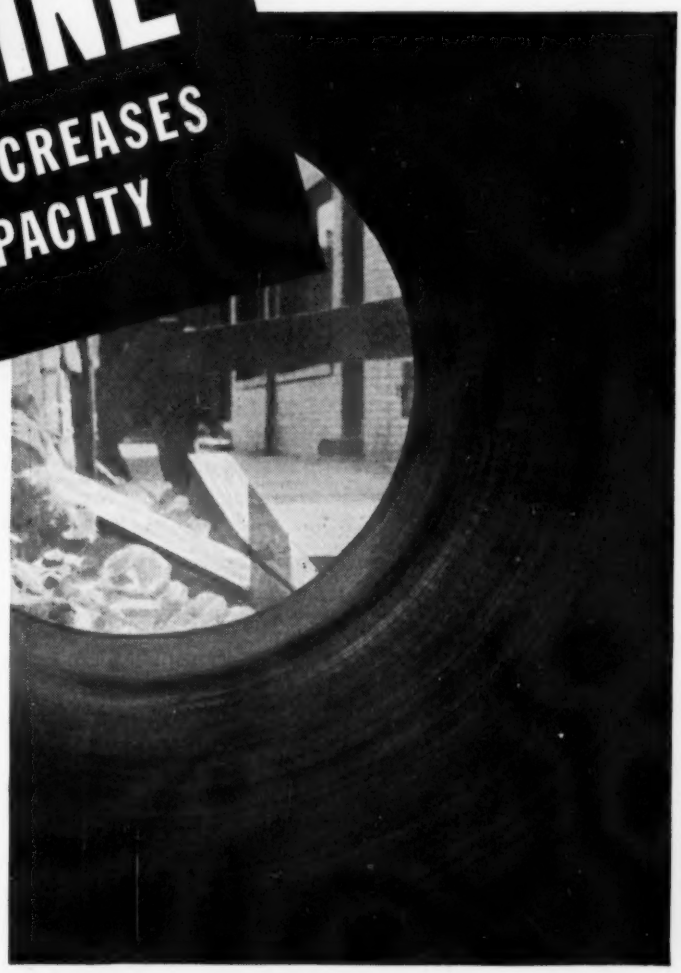
▸▸▸▸ **CENTRILINE** restores the original carrying capacity of old water mains at reasonable cost by the centrifugal application of a cement lining. This smooth, dense, continuous coating defies corrosion and tuberculation. Hence, carrying capacity is sustained for the lifetime of the main.

The ever-smooth, protective lining centrifugally applied by Centriline in some instances has increased carrying capacity beyond the rate of the pipeline when originally installed. This is due to the homogeneity of the lining which covers seams, joints and rivet heads.

If mains are losing their efficiency, consult with our experienced hydraulic engineers.

▸▸▸▸ **WRITE TODAY FOR THE NEW CENTRILINE CATALOG**

CENTRILINE
PERMANENTLY INCREASES CARRYING CAPACITY



CENTRILINE CORPORATION

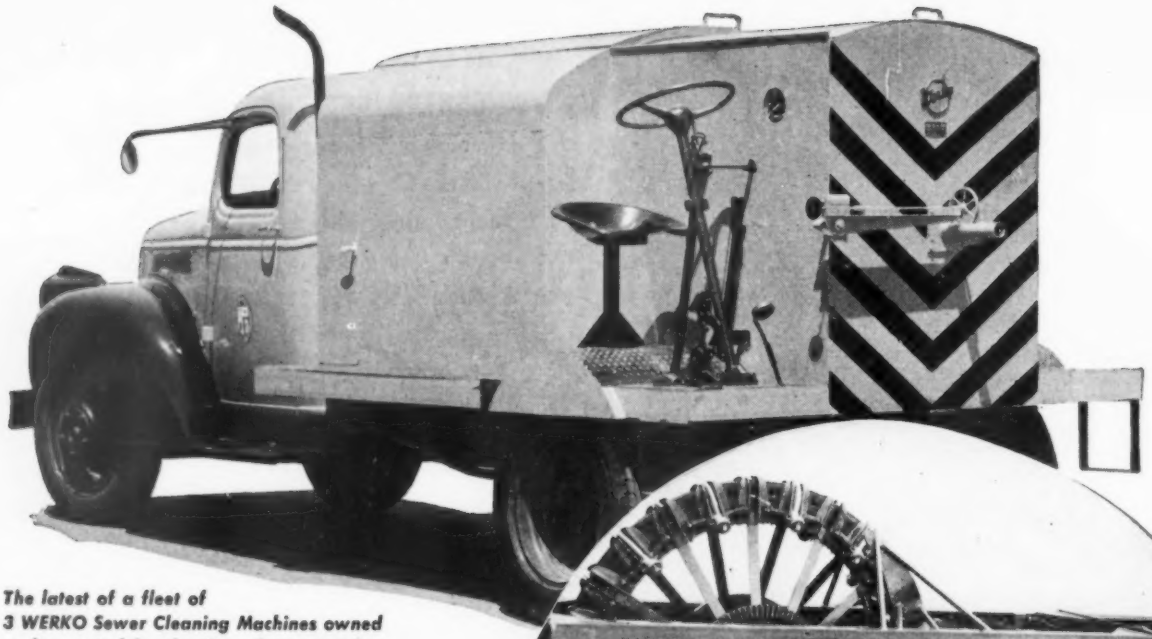
148 CEDAR STREET • NEW YORK 6, N. Y.

CENTRILINE PROCESS

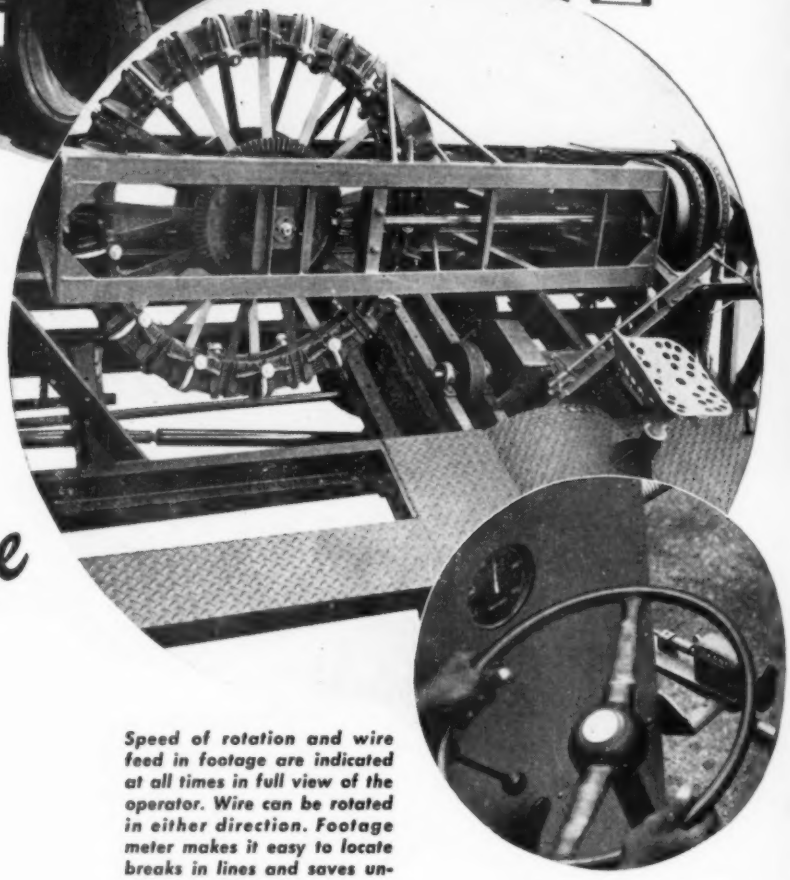
CEMENT MORTAR LININGS FOR WATER MAINS

Centrifugally Applied

In Strict Conformity with A. W. W. A. Specifications



The latest of a fleet of 3 WERKO Sewer Cleaning Machines owned and operated by the City of Los Angeles.



Speed of rotation and wire feed in footage are indicated at all times in full view of the operator. Wire can be rotated in either direction. Footage meter makes it easy to locate breaks in lines and saves unnecessary digging.

Werko PRODUCTS

Cut Your Maintenance Costs!

The WERKO Sewer Cleaning Machine is an investment which pays dividends year after year in lower maintenance costs. It makes possible a planned maintenance program whereby causes of sewer and drain line stoppages are prevented before they can cause serious, costly damage. Lines and structures are protected from deterioration due to bacterial action. Personnel are protected by eliminating bad gas conditions. Lines can be operated at full capacity instead of being clogged up with roots, grease, sand, etc.

The WERKO Unit can be mounted on your own truck chassis by any mechanic. All that is necessary is to bolt the unit to the truck frame and connect the power take-off. Any standard truck with 158" or larger wheelbase can be used. Reel capacity: 1,000 ft. No. 0 oil tempered steel wire. Interchangeable heads are supplied for any conditions such as scale, roots, grease, etc.

Write for details and prices. Deliveries in 60 days from receipt of order.

THE GEO. H. WERFELMAN CO.

Manufacturers: **MUNICIPAL AND INDUSTRIAL PIPE CLEANING MACHINES**

Factory ***Sales***

1060 LILLIAN WAY, LOS ANGELES 38 • P.O. BOX 2590, LOS ANGELES 28

It is going to be one of the biggest conventions in the industry—this first joint get-together of the AWWA and the Sewerage Works Association.

We of the R. D. Wood Company are looking forward to the event with keen anticipation. We expect to have a grand time—meeting old friends, some of them only lately back from the war; and making new friends.

As to our displays (Booth 45). A model of our Mathews Hydrant will be there, you may be sure, along with models and literature of our other products. Though we believe our hydrant to be the best-known in the world, we realize there are waterworks men who are not familiar with it. We'll gladly show you why we've been saying for so long it is the finest hydrant made; and why that's its reputation everywhere.

See you in San Francisco. Booth 45.

MATHEWS HYDRANTS

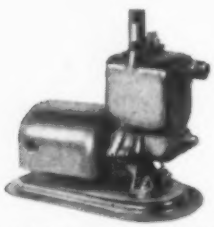
Made by **R. D. WOOD COMPANY**

PUBLIC LEDGER BUILDING, INDEPENDENCE SQUARE, PHILADELPHIA 5, PA.

MAKERS ALSO OF "SAND-SPUN" PIPE (CENTRIFUGALLY CAST IN SAND MOLDS) AND R. D. WOOD GATE VALVES

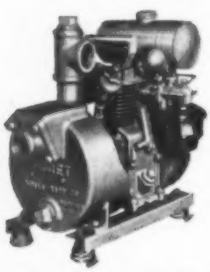
SEPTIC TANK CLEANING

Quick – Easy – Profitable



"HANDY" PUMP

A tiny pump weighing only 27 lbs., remarkable for performance. Fitted with pipe or common garden hose, this pump will lift up to 25 ft. Delivers 8 GPM at 40 lbs. pressure. Electric motor driven – self-priming. An extremely handy, dependable and trouble-free pump for all kinds of pumping jobs.



"MIDGET" PUMP

The ideal, lightweight, self-priming pump. Easily handled – weighs only 60 lbs. Will pump 3000 GPH at 20 ft. head, 5 ft. suction lift. Rapid automatic priming. Husky – trouble free – non-clogging. Whatever your pumping requirements may be up to 125,000 GPH there is a Gorman-Rupp Blue pump to do the job quicker and better.

WITH AN O.S.C. ON THE JOB

The New Odorless Sanitary Cleaner makes the Sanitary Service Operator's job an easy, pleasant and profitable one. Compare the following performance with that of old fashioned, disagreeable and unsanitary methods:

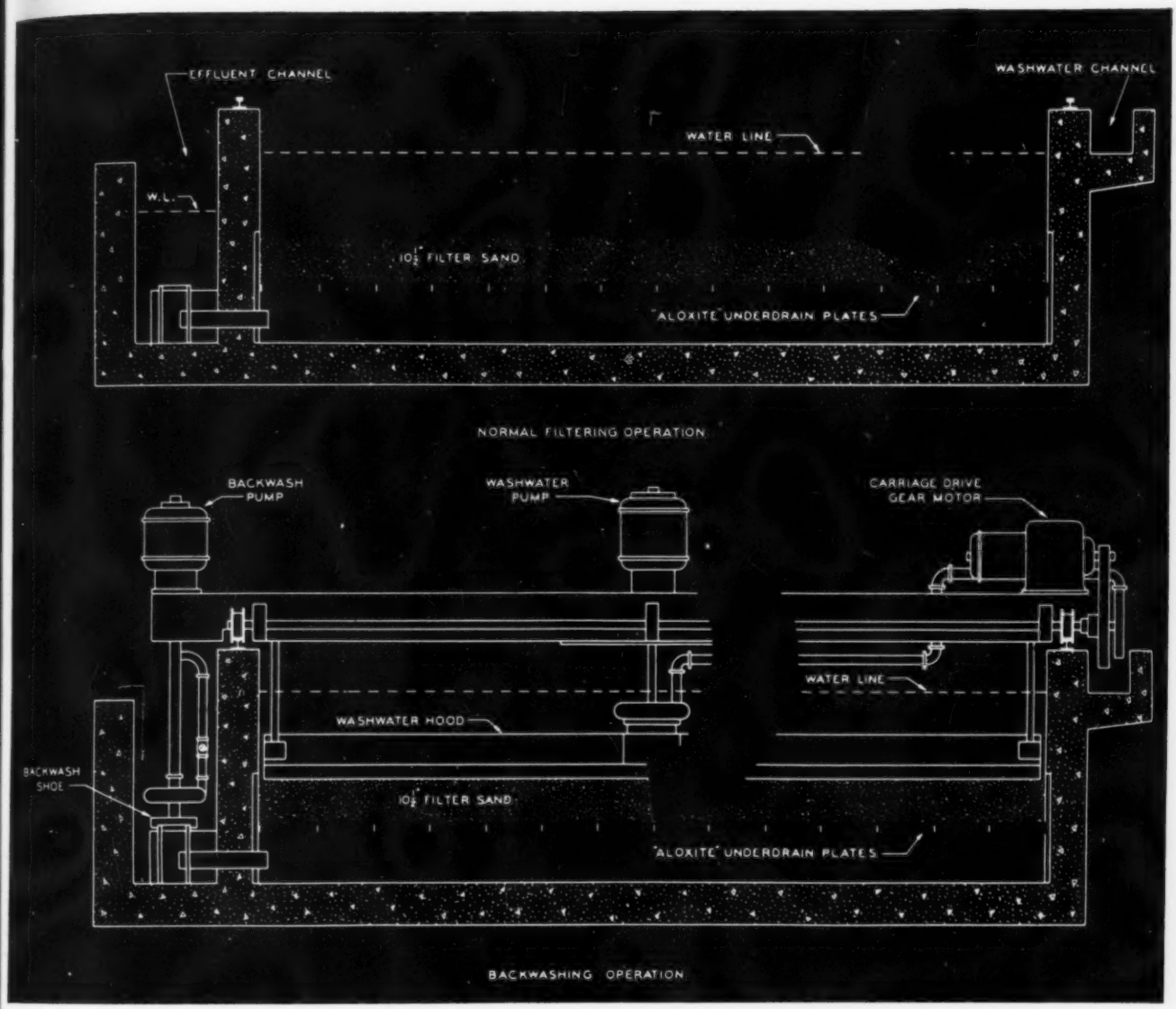
Septic Tanks of 500 gal. size cleaned in 15 minutes; 1000 gal. size in 20 minutes. A 25,000 gal. septic tank was actually cleaned in just 10 hours. Efficient? Yes, but also odorless and sanitary. No open tanks, diaphragm hand pumps, shovels or makeshift equipment. Approved by public health officials.

The O.S.C. is a modern apparatus especially engineered for cleaning septic tanks, vaults and cisterns. It can also be used for emergency fire fighting, sprinkling or dewatering flooded basements. It is equipped with a powerful Gorman-Rupp Centrifugal sewage pump of self-priming design and is shipped ready to mount on standard truck chassis of 158 to 161 inches.

Write for special bulletin 7-ST-11

THE GORMAN-RUPP COMPANY
MANSFIELD • OHIO

Serving Large Paper Mill and Town



● **Hardinge Automatic Back Wash Rapid Sand Filter Using ALOXITE Porous Plates**

Operated steadily for more than a year, this 1100 sq. ft. Hardinge filter, equipped with ALOXITE aluminum oxide underdrain plates, has proved eminently satisfactory. Installed by the paper mill, it supplies water to both mill and town.

Using a 10½" deep sand bed, solids removal of over 97% is accomplished. The effluent averages less than 1 ppm. of suspended solids. And this is achieved without chemical treatment of the raw reservoir water.

With ALOXITE porous plates on the job, there is no need for graded gravel. Eliminated, therefore, are the difficulties encountered so frequently with gravel-sand combinations. Backwash water is distributed uniformly. Affording full use of the automatic backwashing principle as applied to this unit, continuous operation and lower maintenance expense are assured.

Adaptable to new or old, large or small gravity and pressure units, the ALOXITE underdrain system provides highly worth while savings. Check its possibilities for your filters. Complete details will be furnished by our engineers. Write Dept. O-77, The Carborundum Company, Refractories Division, Perth Amboy, New Jersey.

Underdrain Plates

BY CARBORUNDUM

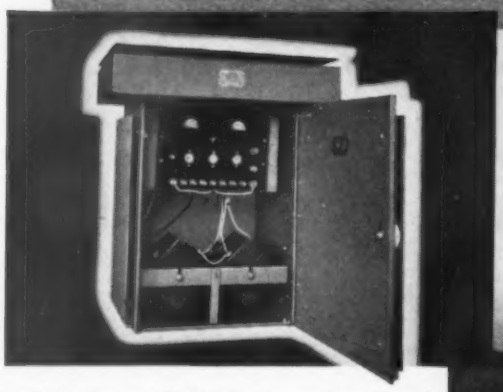
TRADE MARK

"Carborundum" and "Aloxite" are registered trademarks which indicate manufacture by The Carborundum Company

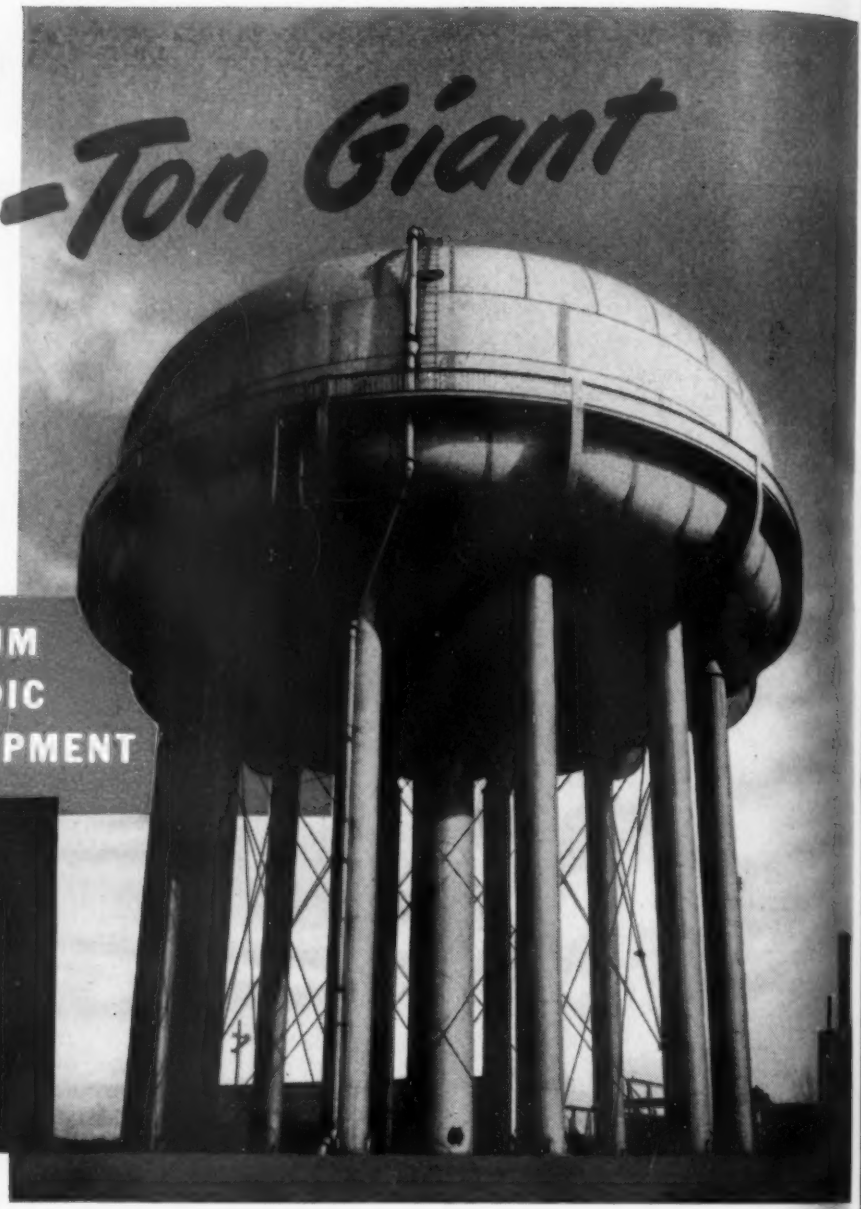
BODY GUARD FOR A 6000-Ton Giant

This Huge Water Tank is Guarded Against Galvanic Corrosion by

FEDERAL'S SELENIUM RECTIFIER CATHODIC PROTECTION EQUIPMENT



This Federal Cathodic Protection Rectifier Equipment converts AC to DC – for cathodic protection of the huge water storage tank at Hammond, Indiana.



The cathodic protection of this 1,500,000 gallon tank was engineered and installed by the Electro-Rust-proofing Corporation, Belleville, N. J., an Associate Company of Wallace and Tiernan Company, Inc.

TAKE a million and a half gallons of water, put it in a huge steel tank, and you have all the elements of a colossal galvanic cell. The water is the electrolyte, and sections of the interior of the tank become the anodes. The flow of galvanic current from these local cells on the tank walls through the water results in corrosion that often makes it necessary to repaint the tank interior *twice a year!*

This 1,500,000 gallon tank—part of the water works system of the city of Hammond, Indiana—demonstrates the modern low-cost method of preventing galvanic corrosion, by *cathodic protection*. A Federal Selenium Rectifier equipment provides a continuous supply of direct current which flows *from* a sacrificial anode through the water *to* the tank and stops corrosion by neutralizing the local galvanic currents. This rectifier equipment operates silently, automatically, 24 hours a day. It has no moving parts—operates for long periods of time with minimum attention and maintenance.

Federal Cathodic Protection Equipments have proved their reliability and economy in hundreds of installations—protecting pipe lines, storage tanks and cable systems. For information on Federal Selenium Rectifier Cathodic Protection Power Supplies write to Federal today. Dept. E 152.

KEEPING FEDERAL YEARS AHEAD... is IT&T's world-wide research and engineering organization, of which the Federal Telecommunication Laboratories, Nutley, N. J., is a unit

Federal Telephone and Radio Corporation

SELENIUM and INTELIN DIVISION, 1000 Passaic Ave., East Newark, New Jersey

In Canada: — Federal Electric Manufacturing Company, Ltd., Montreal.
Export Distributors. — International Standard Electric Corp., 67 Broad St., N.Y.C.

ZECO GREENSAND ZEOLITE

ZECO and HI-ZECO Greensand Zeolite for water softening, filtration and iron removal. ZECO Manganese Zeolite for iron and manganese removal. COREXITE mineral for corrosion control and water stabilization.

★

ZEOLITE CHEMICAL CO.

Sales Office
140 Cedar St., New York, N. Y.

Factory
Medford, N. J.

Pioneer Producer of GREENSAND ZEOLITE MINERAL

Advertisement JULY, 1947

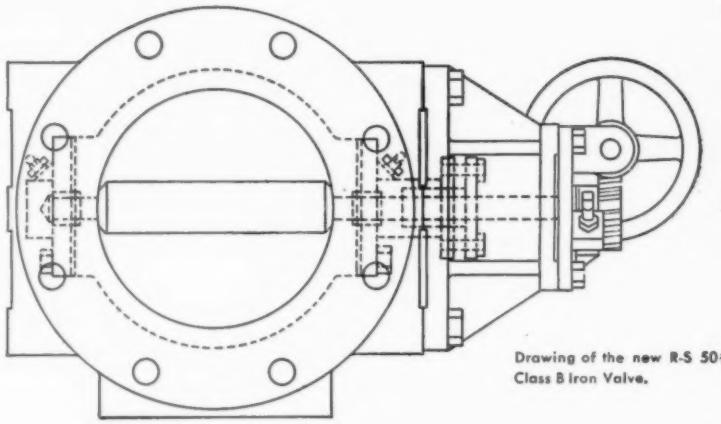
R-S valvEvents

ISSUED PERIODICALLY BY R-S PRODUCTS CORPORATION, PHILADELPHIA 44, PA., FOR THOSE CONCERNED WITH FLOW CONTROL AND SHUT-OFF

Here is the New 50 pound R-S Class B Iron Valve

The print shows the construction of a new member of the R-S Valve family. This R-S Butterfly Valve is made for rugged hydraulic service with a large safety factor for line stresses, water-hammer, and other abuses. It is enjoying excellent acceptance for use in circulating water lines for condenser service. Available with 25# or 125# American Standard flanges. The usual four types of manual control or a multiplicity of automatic controls may be fitted. Supplied in any metal that can be cast or welded, including steel with Series 15 150# American Standard flanges.

The new valve has the characteristic R-S angular seating disc giving wedge-type closure. It may be equipped with the renewable, replaceable R-S patented rubber spool for 100% positive shut-off if desired. This type of unique R-S shut-off has been tested in service for as many as 10,000 violent full-open-to-full-closed sequences without a trace of leakage. (Good to the last drop!)



Drawing of the new R-S 50# Class B Iron Valve.

R-S Rubber-seated Butterfly Valve Now Available up to 72-inch Size!

Patented renewable replaceable rubber liner

Installing liner in valve body

Rubber liner in position

The growing demand for complete shut-off in the Butterfly Valve is leading to the development of larger and larger sizes in the R-S Rubber-seated unit.

Having completed the line up to and including the 72-inch size, we are now working on sizes up to and including 108-inch diameters.

These large sizes are Colossal. When we build larger ones they will be Titanic. The larger sizes are identical in *functional* characteristics with the 6-inch rubber-seated valve illustrated. The unique R-S spool provides for the first time in the history of Butterfly Valves a 100%-effective heavy-duty shut-off. It operates with complete success in the temperature range from —20° to plus 200°F., and we are in the process of perfecting R-S "H" rubber for higher and lower temperatures.

Perfect closure is made by the wedge-like action of the butterfly disc closing inside a one-piece flexible rubber spool. The spool bunches up around the periphery of the disc to make drop-tight closure even at the shaft-bosses. A special composition of rubber and other materials assures retention of resilience and wearing qualities for an amazingly long time.

The spool is renewable and replaceable as shown in the illustration. The flanges of the spool, drilled to fit body-flange holes, take the place of the usual flange-gaskets. The rubber-seated valve has been giving exceptionally good service in handling gases, liquids, powdered materials and other semisolids; in fact anything that can be pushed through pipe lines. Patent is pending.

R-S Butterfly Valves may also be had with a rubber lining if desired. The rubber lining, in addition to positive shut-off also offers complete protection of body, shaft, bushings, etc., from liquids and gases of a corrosive nature.

Wider Representation of R-S Butterfly Valves

Four new representatives, three in new territory, are now handling R-S Valves. We are glad to announce the new distributors to R-S customers in the following places:

Richmond, Virginia
Frank Howell Company, American Building, Richmond 1, Virginia, handling the state.

Charlotte, North Carolina
Purser & London, Inc., 816 Independence Building, Charlotte, North Carolina, handling the Carolinas.

Venezuela
Roberto Diaz, Caracas, Venezuela, handling the entire country.

Panama
Agencias Pan-Americanas, S. A., Calle Estudiante No. 90, Apartado 557, Panama, Rep. de Panama, handling the entire country. W. S. Eskildsen is in charge.

Complete R-S Valve Installation Data

Engineers like the complete dimensional data supplied for R-S Butterfly Valves. Dimensions are tabulated by standard sizes under stock types and identified by letters corresponding to detailed drawings which accompany the tables. Six full pages of R-S Products' Catalog No. 14-B (copy on request to R-S Products Corporation, Wayne Junction, Philadelphia 44, Pa.) are devoted to this basic installation data.

JMLco P-G2

Personal pride in PRECISION PRODUCTION

WITH the pride of watchmakers, Badger craftsmen produce the many precision parts used in Badger Water Meters. That is one reason why years of accurate metering are yours when you use Badger Meters.

Send us the coupon. It will bring a Badger Meter Engineer who will show you all the reasons why you get "More for your money," when you buy Badger Water Meters.

BADGER METER MFG. CO.
MILWAUKEE 10, WISCONSIN

BRANCH OFFICES:

New York City - Chicago, Illinois - Waco, Texas - Portland, Ore. - Salt Lake City, Utah - Seattle, Wash. - Cincinnati, Ohio - Philadelphia, Pa. - Denver, Colo. - Worcester, Mass. - Kansas City, Mo. - Tampa, Fla. - Savannah, Ga. - Los Angeles, Calif.

BADGER METER MFG. CO. • MILWAUKEE 10, WISCONSIN

☐ Please have a Badger Meter Representative call.
☐ Please send complete descriptive literature.

Name of Utility_____

Individual_____ Title_____

Street Address_____

City and State_____

SERVICE . . .

. . with a *wrench!*

Easy servicing is another one of the reasons why you'll go big for LUDLOW Hydrants! One man with a wrench can remove stem and working parts as a single unit whenever maintenance or inspection is required. There's nothing to unscrew below the ground level!

IMMEDIATE SHIPMENT!

HUB END VALVES

Double Gate—A.W.W.A. Specifications 2 in. to 12 in.

Also Normal Delivery on Valves in Larger Sizes and *rapid delivery* on Hydrants

H-71

THE LUDLOW VALVE MFG. CO., INC., TROY, N.Y.

LUDLOW HYDRANTS

Superior Features Since 1866

a for every and

Preventing and curing water-line headaches is largely a matter of having the right pipe joint or repair product for each specific need. Engineered to solve your problems, Dresser's complete line provides labor-saving, economical products for efficient and permanent pipe joining and repair.

● WHERE DRESSER PRODUCTS CAN SERVE YOU

Here are some of the many installations on which Dresser Couplings and Repair Products can save you time, trouble and expense:

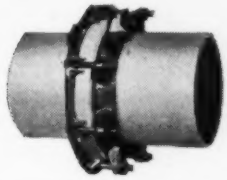
Water supply lines	Pumping stations	Sprinkler system piping
Distribution lines	Filtration plants	Sewer trunk lines
Intakes	Pump connections	Outfalls
Subaqueous lines	Penstocks	Force mains
Bridge crossings	Air conditioning piping	

● LATEST DRESSER CATALOG

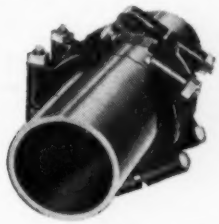
For detailed information on how Dresser products can simplify your pipe joining and repairing problems, write on your letterhead for a copy of the new No. 47 Dresser Catalog.

REPRESENTATIVE DRESSER PRODUCTS

Steel Couplings (Style 38) for joining plain-end steel and cast iron pipe. Sizes from ⅜" to 72" and up.

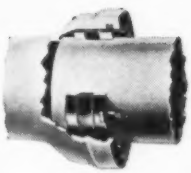


Adjustable Bell-Joint Clamps (Style 60) for repairing and preventing leaks in bell-and-spigot joints. Sizes 3" to 60" CIP.



"Adjustable" Repair Sleeves (Style 82) for quick, permanent repair on cast iron lines. Sizes 4" to 8".

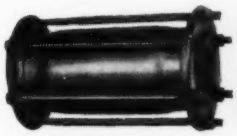
Split Repair Sleeves (Style 57C) for repairing breaks, splits and holes in CIP. Sizes from 2" to 12".



Bellmaster Joints (Style 85) for Bellmaster cast iron pipe. Fits inside bell. Sizes 3" to 12".

Malleable and Steel Saddles (Style 91) for service connections to steel and cast iron pipe. Sizes 1¼" ID to 20" OD.

Boltless Fittings—Style 90 for service lines—Style 65 for equipment piping—Style 88 for copper tubing. Sizes 2" and smaller.

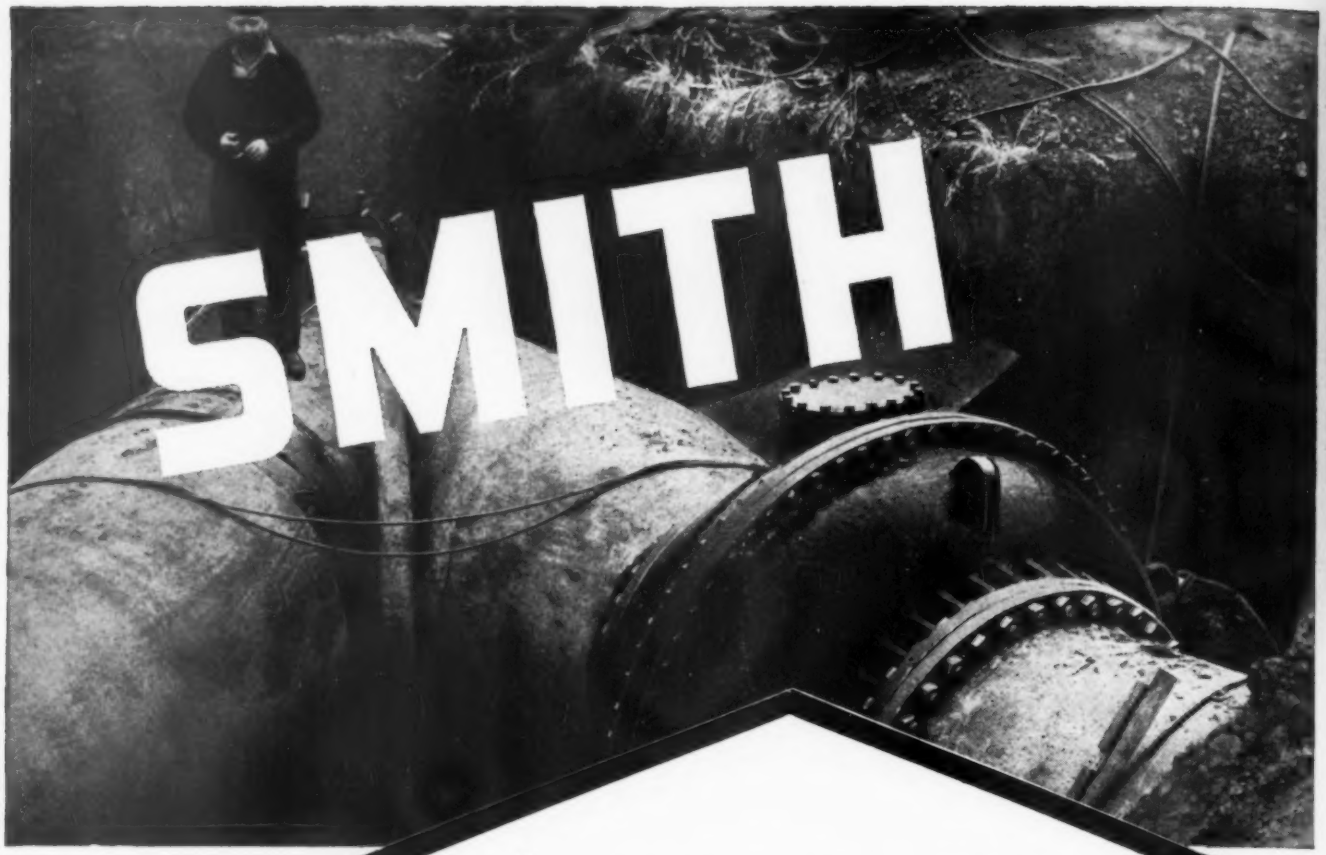


Long Sleeves (Style 40) to span gaps between pipe ends. Simplifies tie-ins. Sizes from ½" to 24".

DRESSER COUPLINGS and REPAIR PRODUCTS

ONE OF THE DRESSER INDUSTRIES

DRESSER MANUFACTURING DIVISION, BRADFORD, PA. • 1121 ROTHWELL ST., HOUSTON, TEXAS.
IN CANADA: DRESSER MANUFACTURING CO., LTD., 60 FRONT ST., W., TORONTO, ONTARIO



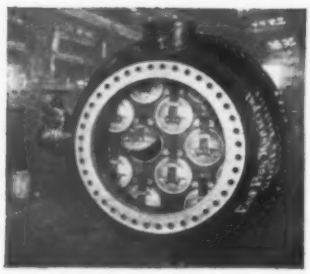
MULTI-PORT CHECK VALVES END WATER HAMMER RISK

AT EAST BAY, CALIFORNIA

To avoid water hammer resulting from shutdown of pumping units employed to boost the capacity of a gravity feed line, this 54″ Smith Multi-port, disk check valve was installed in a by-pass around the pump. When pumps are operating, greater pressure on the downstream side holds the valves closed. When pumps are suddenly stopped, the downstream pressure becomes less than the upstream pressure and the multi-port valves open, permitting aqueduct flow to continue at a gradually diminishing rate.

Large high pressure, multi-port check valves are but one of many Smith products furnished to the water works industry. See list below.

25



Smith 54″ cast steel, multi-port, check valve—200 lb. working pressure.

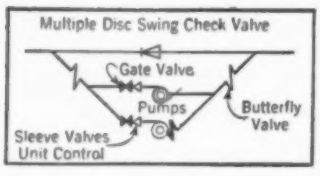


Diagram showing location of the multi-port valve.

FIRE HYDRANTS
GATE VALVES
CHECK VALVES
INSERTING VALVES
TAPPING SLEEVES AND VALVES
WATER SERVICE BRASS GOODS

THE A. P. SMITH MFG. CO.

EAST ORANGE, NEW JERSEY

FLOOR STANDS
INDICATOR POSTS
TAPPING MACHINES
INSERTING MACHINES
PIPE CUTTING MACHINES
CORPORATION TAPPING MACHINES

You are cordially invited to visit A. P. Smith Booth 55 at the San Francisco Convention.

Modern Sewage Treatment Plants

require equipment that has proved itself efficient and is backed by individual responsibility for design, engineering, fabrication and initial operation.

General American Conkey Sludge Filters—the first to be used for large scale dewatering of sludges such as primary, elutriated-digested, Guggenheim Process, etc.—are dewatering more than a thousand tons of dry solids daily.

General American Louisville Dryers have been successfully used for years drying both activated and digested sludges. Type "L", with patented fire-conduits to eliminate scorching or burning, produces a uniformly high quality maximum yield of dried product for fertilizer or earth conditioner.

Let the experience and knowledge of General American engineers help you while your plans are in the blue print stage.

★ ★ ★ ★ ★

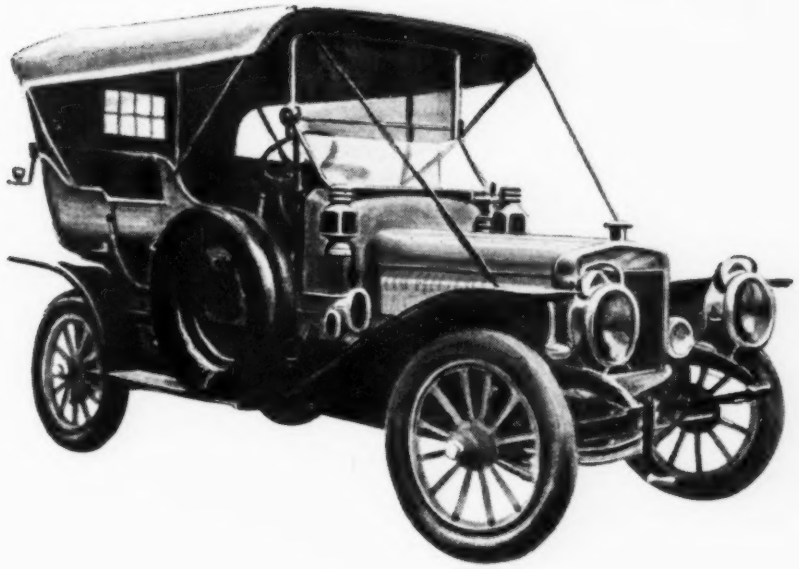
OTHER GENERAL AMERICAN EQUIPMENT

SCREENING DRYERS
SLUDGE GAS HOLDERS
GARBAGE DRYERS
HYDROSEPARATORS
STORAGE TANKS
WATER TANKS
TURBO-MIXERS
THICKENERS
STEEL-ALLOY PLATEWORK
STEEL STACKS

General American
TRANSPORTATION CORPORATION
process equipment • steel and alloy plate fabrication

SALES OFFICE: 10 East 49th St., Dept. 830b, New York 17, N. Y.
WORKS: Sharon, Pa., East Chicago, Ind.
OFFICES: Chicago, Sharon, Louisville, Orlando, Washington, D. C.
Pittsburgh, St. Louis, Salt Lake City, Cleveland.

GATX GENERAL AMERICAN



THE AUTOMOBILE WAS A RICH MAN'S TOY

THE AUTOMOBILE WAS A RICH MAN'S TOY—but today nearly everyone drives a car.

An important reason for the rapid success and wide acceptance of the automobile is that it was designed and engineered for a single purpose . . . to provide better transportation.

The same reason accounts for the rapid success and wide acceptance of Transite Pressure Pipe. It, too, was designed and engineered for a single purpose . . . to carry water more efficiently.

J-M engineers combined asbestos and cement under great pressure, produced a material that did a better job. The new material was called Transite. Transite is rustproof, it cannot tuberculate, it resists even the most corrosive soils.

Then they designed a coupling made of Transite and named it the Simplex Coupling. Simple and effective, it consists only of a Transite sleeve and two rubber rings tightly compressed into position between sleeve and pipe. This construction guards against leakage and also provides flexibility at each joint. The flexibility helps to cushion the entire line against shock and soil stresses, permits a deflection up to 5 degrees at each joint.

Today you can have the engineering progress that goes into a streamlined car when you travel today's highways. Probably you'll want the advantages of modern engineering in the field of water transportation too.

Then remember this important fact. *Transite Pressure Pipe was engineered for the single purpose of transporting water more efficiently.*

For all the facts about Transite, the *modern* water pipe, write Johns-Manville, Box 290, New York 16, New York.

JOHNS-MANVILLE JM PRODUCTS

Worthington-Gamon WATCH DOG WATER METERS

The meter used by thousands of municipalities in the U. S. and abroad.

SURE TO MEET YOUR SPECIFICATIONS FOR ACCURACY, LOW MAINTENANCE, LONG LIFE

Before you invest in water meters, get acquainted with the design and performance advantages which make Worthington-Gamon Watch Dog Water Meters first choice of so many municipalities and private water companies in the United States.

WATCH DOG WATER METERS

"Watch Dog" models . . . made in standard capacities from 20 gpm up; frost-proof and split case in household sizes. Disc type, Turbine type or Compound type. Write for Bulletin.

GS-2

WORTHINGTON-GAMON METER COMPANY

296 South Street, Newark 5, New Jersey

Subsidiary of

WORTHINGTON

PUMP AND MACHINERY CORPORATION

When Point Pleasant Beach, New Jersey, needed an outfall line, the Borough Engineer quite properly investigated the practice and experience of other municipalities with similar installations. What did he find? Fourteen communities in New Jersey alone, with outfall lines of Byers Wrought Iron. Records of service ranged up to 20 years or more, providing an excellent index to durability. As a result, the Borough selected Byers Wrought Iron pipe for the projected line.

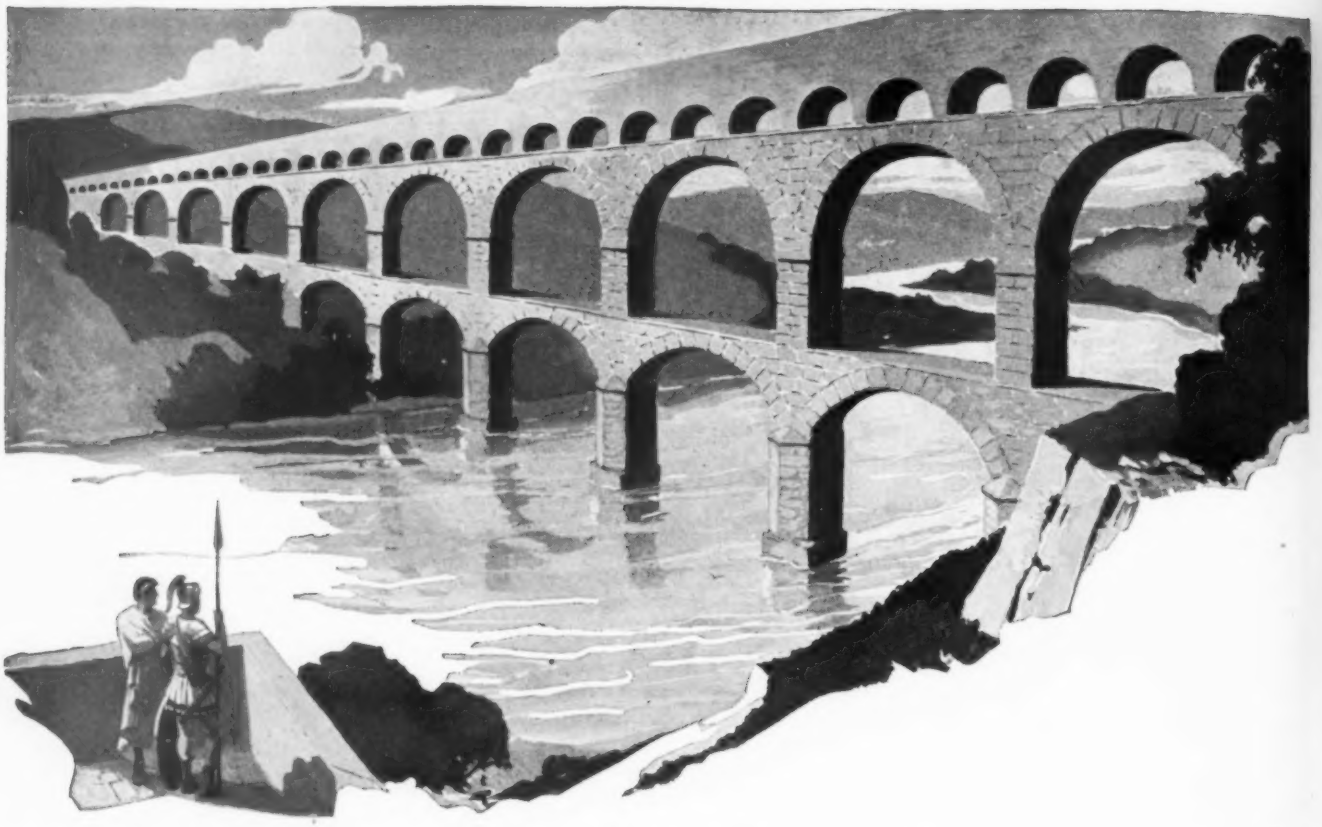
The illustration shows the 12-inch, 1200-foot wrought iron line during installation. Sections are welded, and each joint is enclosed in a split sleeve, fabricated of 14-inch OD wrought iron pipe with ½-inch wall. As sections are added, the line is moved out to sea by tackle attached to loops welded to the pipe wall. The free end of the line is carried by the two vessels visible in the distance. Work was handled by Thomas Proctor Company, which has made a number of outfall installations along the Atlantic coast.

Outfalls face a variety of severe conditions: Corrosion from within and without, shocks and strains from tides, and severe stresses due to shifting bottom, which may leave long spans unsupported. The unique composition and structure of Byers Wrought Iron provides the needed service qualities. The tiny fibers of glass-like silicate slag threaded through the body of high purity iron halt and "detour" corrosive attack, anchor the protective scale which shields the underlying metal, and give a "hickory-like" structure that withstands shock.

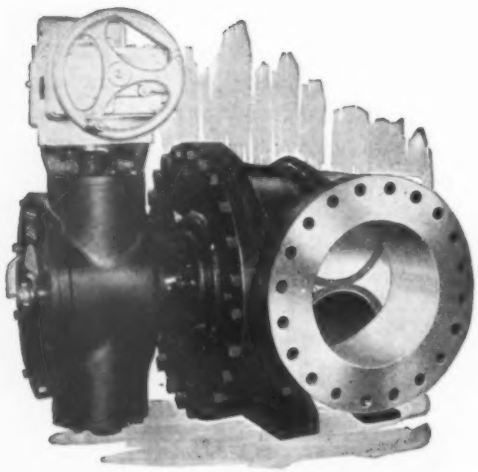
Our bulletin, "Wrought Iron for Sewage Treatment and Disposal Installations," gives helpful information on a number of outfall jobs. Ask for a copy.

A. M. Byers Co., Pittsburgh, Pa. Established 1864. Boston, New York, Philadelphia, Washington, Atlanta, Chicago, St. Louis, Houston, Salt Lake City, Seattle, San Francisco.

CORROSION COSTS YOU MORE THAN WROUGHT IRON



a "Big Inch" of olden days—



GENIUS has raised her head in every age. So today's Masterbuilders are but the projeny of antiquity's great inventors. Even principles are related. An example of this is the plug cock design for fluid control, embodied in the Smith Rotovalve, which has come down through the ages unchanged! Send for your copy of "Rotovalves by Smith."

If It's Hydraulics—
Put It Up To Us!

S. MORGAN SMITH Co.
YORK, PENNA. U.S.A.

Water
as pure as a
Mountain Stream

DIAMOND

Liquid Chlorine

keeps your water pure, safe and palatable

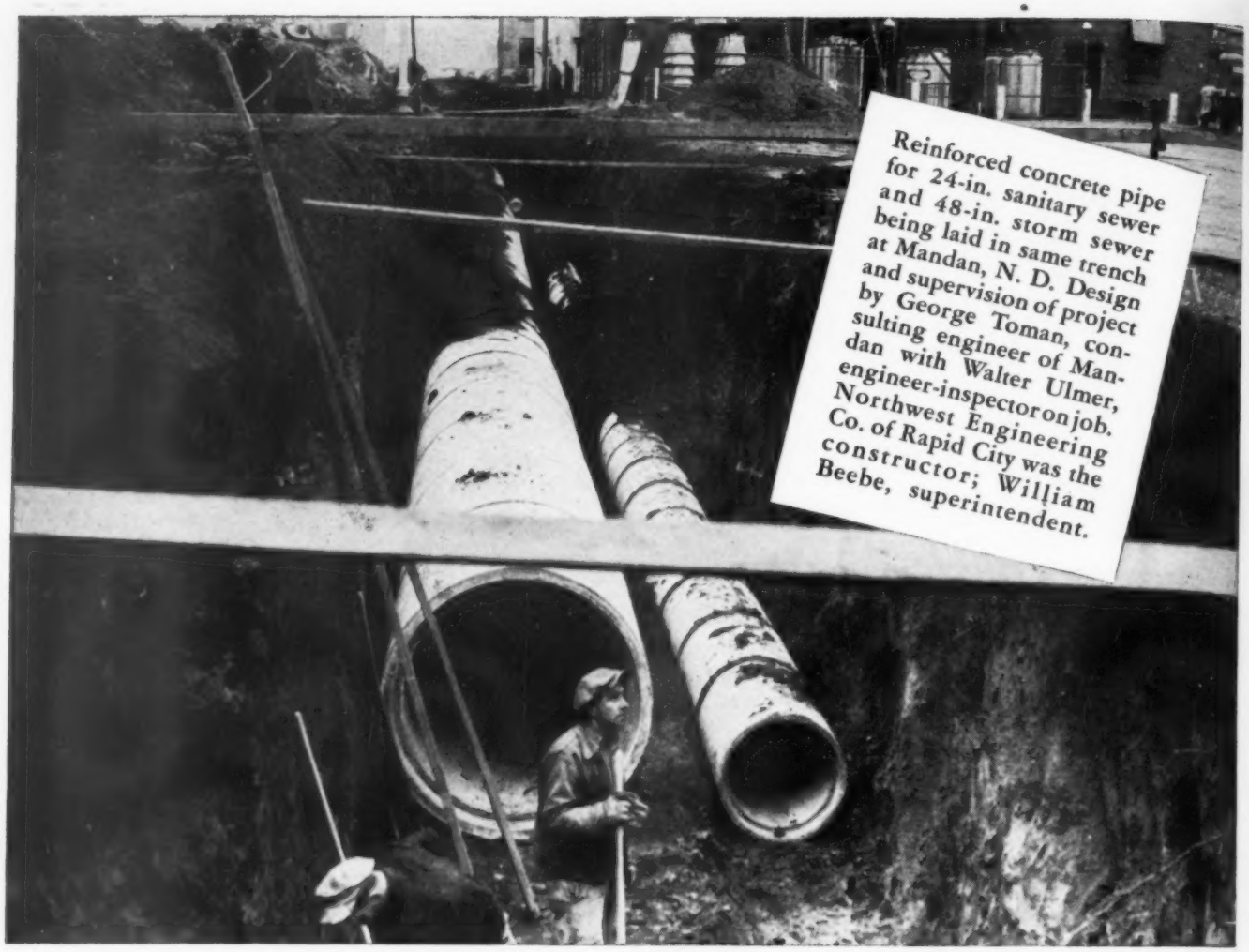
The ever-increasing demand and necessity for pure, safe and palatable water, make DIAMOND Liquid Chlorine—with its dependable high quality and uniformity—a "must" for modern water treatment. Close control of all manufacturing processes guarantees year-round satisfaction.

Furnished in cylinders, multi-unit or single-unit tank cars to suit your needs. Write today for complete data.

DIAMOND ALKALI CO.

Pittsburgh 22, Pa., *and Everywhere*

CHLORINE



Reinforced concrete pipe for 24-in. sanitary sewer and 48-in. storm sewer being laid in same trench at Mandan, N. D. Design and supervision of project by George Toman, consulting engineer of Mandan with Walter Ulmer, engineer-inspector on job. Northwest Engineering Co. of Rapid City was the constructor; William Beebe, superintendent.

Mandan, N. D. Builds for Future with *CONCRETE PIPE*

EXTENSIONS to the sanitary sewer facilities and storm drainage system of Mandan, N. D., completed with reinforced concrete pipe in 1946, prepares that city for future residential and industrial growth.

The use of concrete pipe assures the city of Mandan many years of efficient operation of its sewer and storm drainage systems at low annual cost because concrete pipe lines have:

AMPLE STRENGTH to resist the most severe conditions of load and impact;

MAXIMUM CARRYING CAPACITY is assured by clean, even joints and smooth texture of inside surface;

HIGH WEAR RESISTANCE to abrasion caused by suspended grit;

MINIMUM INFILTRATION AND LEAKAGE assured by tight joints and uniformly dense concrete.

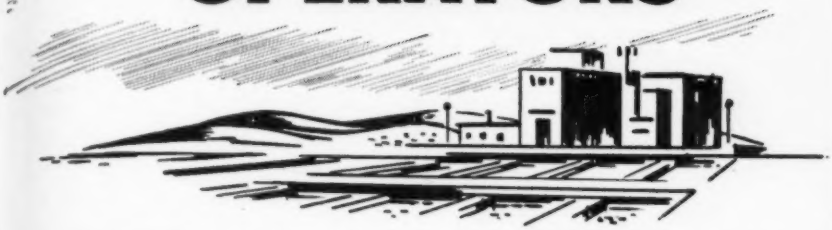
In common with all concrete pipe made by our members, the pipe supplied for the Mandan project complies with standard specifications of the American Society for Testing Materials and the American Association of State Highway Officials.

Technical information on concrete pipe line construction will be gladly furnished by this Association or any of its members. (List of members on request.)

AMERICAN CONCRETE PIPE ASSOCIATION

228 NORTH LA SALLE STREET, CHICAGO 1, ILLINOIS

Important FACTS ABOUT pH for WATER & SEWAGE OPERATORS



WHETHER YOU ARE building a new plant or modernizing present equipment, one of the most important advancements you can make in either water or sewage plants is the installation of BECKMAN pH CONTROL. Through the magic of proper pH control you can make *many* vital savings . . . savings that will quickly pay for the installation and will *continue* paying big dividends throughout the years. For example, some of the many benefits resulting from Beckman pH Control include . . .

WATER PLANTS: Maximum coagulation in settling basins . . . better control of chemicals and treatment during lime-softening operations . . . accurate control over alkalinity of finished water after recarbonation . . . reduction of corrosion in mains and pipe lines . . . and many other important savings.

SEWAGE PLANTS: Optimum sludge digestion . . . more efficient sludge filtration . . . better coagulation . . . accurate control over fluids discharged into rivers and lakes . . . and other vital savings in operating costs.

BUT TO MAKE CERTAIN you get the latest, most convenient and most accurate pH equipment available, *be sure to specify* "BECKMAN" . . .

Beckman pH equipment is completely electrometric, eliminating the mess and inaccuracies of colorimetric methods. Simply press a button and the exact pH of any process is instantly shown on a large easily-read dial. *It is the simplest of all pH methods!*

The accuracy of Beckman pH readings is completely unaffected by human errors in color judgment, by turbidity, oxidizing or reducing agents, by suspended materials, colored process solutions or other variables that affect outmoded colorimetric methods. *Beckman pH readings are universally accurate and dependable!*

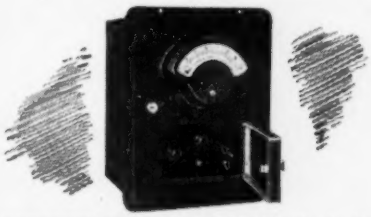
With Beckman equipment no time-wasting or troublesome sampling devices are needed. Beckman pH electrodes may be installed directly in vats, tanks, channels or flow lines—and exact pH values read instantly—and continuously, if desired—on the process fluids themselves.

Unique rugged-type Beckman Electrodes, specially designed for direct immersion in abrasive or suspension-laden fluids, reduce maintenance to an absolute minimum. *Beckman is the most trouble-free of all pH equipment!*

The above are only a few of many Beckman advantages. Write for the complete story.

New Bulletin In Production! *A new Beckman Bulletin outlining various pH applications and methods for water and sewage operations is now in preparation and will be printed soon. Reserve your free copy of this instructive booklet now by sending your name and address. Ask for Bulletin 180!*

THERE'S A BECKMAN pH INSTRUMENT FOR EVERY NEED



COMPLETELY AUTOMATIC! The Beckman Model R instrument operates directly from standard 110 v. A.C. lines to provide completely automatic pH indication. Also provides for completely automatic pH recording and automatic process control. Can be installed to give accurate pH readings from various stations in plant through one instrument. *This is the pH unit being installed by today's most modern plants, large and small.*

PORTABLE A.C. OPERATION! The Beckman Model H instrument can be quickly moved from one part of the plant to another and plugs directly into standard 110 v. 50/60 cycle A.C. current. Compact, convenient and extremely simple to operate, the Model H gives instant pH readings on an easily-read dial. It is widely used both for manual pH control of small plants and as an auxiliary instrument on completely automatic pH installations.

COMPLETELY SELF-CONTAINED! The Beckman Model M is the ideal pH instrument where *complete* portability is desired. Operating from its own self-contained, long-life power supply, the Model M can be used *anywhere* in the plant or field, whether convenient to power lines or not. Features the same accuracy, simplicity and operating speed as the Model H, and is also widely used both for manual pH control of small plants and as auxiliary equipment on large automatic installations.

Write for literature on Beckman pH Equipment!

BRING YOUR pH PROBLEM TO US. Our trained engineers will gladly study your problem and recommend the equipment best suited to your particular requirements. No obligation, of course.

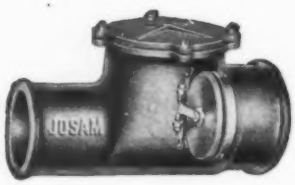
BECKMAN

BECKMAN INSTRUMENTS

National Technical Laboratories • South Pasadena 20, California

INSTRUMENTS CONTROL MODERN INDUSTRIES

PROTECTION *for* PIPE LINES

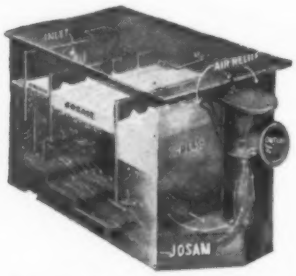


SEWER VALVE Series 1170

Flap is normally open ¾" to allow continuous circulation. Can be adjusted to closed seat type if desired. Inside of valve is offset to prevent fouling. Flap closes tightly with slightest backflow, preventing entry of any backwater or sewage through the drain lines. Supersensitive side swing flap opens wide to permit full water way up to size of pipe for which it was designed.

FLAP VALVE Series 1100½

When placed at the discharge end of sewer pipes, the Josam Flap Valve is an absolute safeguard against the backflow of sewage. In sewer lines it can be placed at the manhole. It will also serve as a sluice, river or tide water outlet and can be used between settling basins in sewage disposal plants.

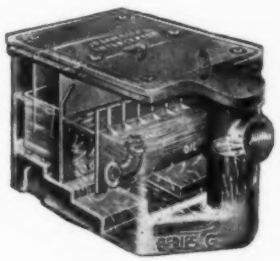


GREASE INTERCEPTOR

The Josam Cascade Grease Interceptor provides maximum grease interception and retention for all types of installations. Grease is removed from waste water before it clogs drain lines. Made in types and sizes for any requirement. Equipped with flow control to insure maximum grease retention efficiency.

SHOCK ABSORBERS for Water Supply Pipe Lines

To eliminate disturbing noises and overcome destructive pounding of water hammer in pipe lines. Especially desirable where quiet is essential. Prevents breakdown of pumps, valves, connections, machinery and equipment.



GAS-OIL INTERCEPTOR

The Josam Gas-Oil Interceptor separates dangerous volatile liquids from waste water or drainage systems, and safely ejects them. Prevents fire, explosion and water pollution. Equipped with flow control to provide maximum interception efficiency. Made in a wide range of types and sizes.

Josam PRODUCTS STANDARD OF AMERICA ESTABLISHED 1918

WRITE FOR INFORMATION AND FREE LITERATURE ON THESE JOSAM PRODUCTS

Original Double Drainage Floor, Roof and Shower Drains • Genuine Non-Clog Triple Drainage Floor Drains
Backwater Sewer Valves • Interceptors • Shock Absorbers for Pipe Lines • Moderator
Mixing Valves for Showers • Swimming Pool Equipment

JOSAM MANUFACTURING COMPANY

General Offices:
320 Ferguson Bldg., Cleveland 14, Ohio

Plant:
Michigan City, Indiana

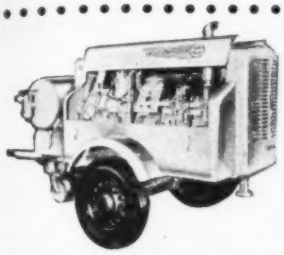
REPRESENTATIVES IN ALL PRINCIPAL CITIES

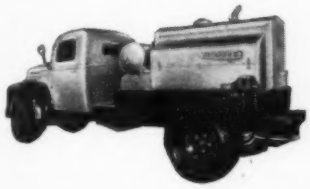
JOSAM-PACIFIC CO.
West Coast Distributors
765 Folsom St., San Francisco, Cal.

EMPIRE BRASS CO., LTD.
Canadian Distributors
London, Ontario, Canada

THERE ARE NO SUBSTITUTES FOR JOSAM PRODUCTS

JAEGER Precision-Built Compressors





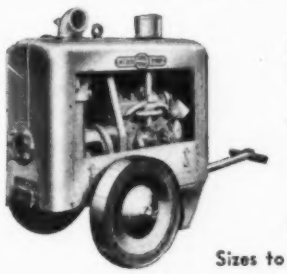
Built to the Micro-Precision Standards of Fine Engines in Balanced 2-Stage, Air-Cooled Units of 60 to 600 Cu. Ft. Capacity — Sold, Serviced in Over 120 Cities.

Buyers who know their air costs — in pounds of fuel for air delivered, in oil consumption, mechanical upkeep and long-term replacement — are today's big users of Jaeger "AIR PLUS" Compressors. Jaeger valves are 75% to 100% larger for free air flow and coolness and "ultra lapped" to positive, leak-proof closure. Balanced "W" type compressor operates at 20% to 30% slower, cooler piston speed (800 f.p.m.) is force feed lubricated. Intercooling is 100% efficient, provides automatic drainage.

Lifetime clutches, 30% to 50% larger air receivers, sectional radiators, bigger tool boxes, electric starters, grouped controls, Timken bearing wheels, etc., are all standard features.

JAEGER Enclosed-Type Pumps . . . . .

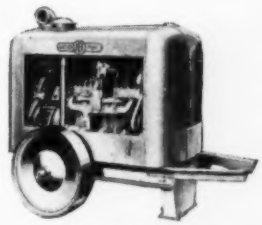
3,000 Gallon "Bantam"



Sizes to 10"

Jaeger developed and brought to peak efficiency the modern, compact, portable, self-priming centrifugal and now protects that efficiency by over-all enclosures which insure a dry, clean, quick-starting and smooth running unit under all weather conditions.

Doubly sure and fast priming action, extra power from bigger engines, high pressure shell construction of self-cleaning design, replaceable liners, longest-life seals and micrometer workmanship are Jaeger features. Every pump is factory tested and certified. Capacities up to 240,000 g.p.h.



Self-Priming Jet Pumps, up to 250 lbs. pressure.

Leading distributors in over 120 cities sell, rent, service Jaeger Compressors, Pumps, Mixers, and other equipment. Send for Catalogs and name of your local Jaeger dealer.

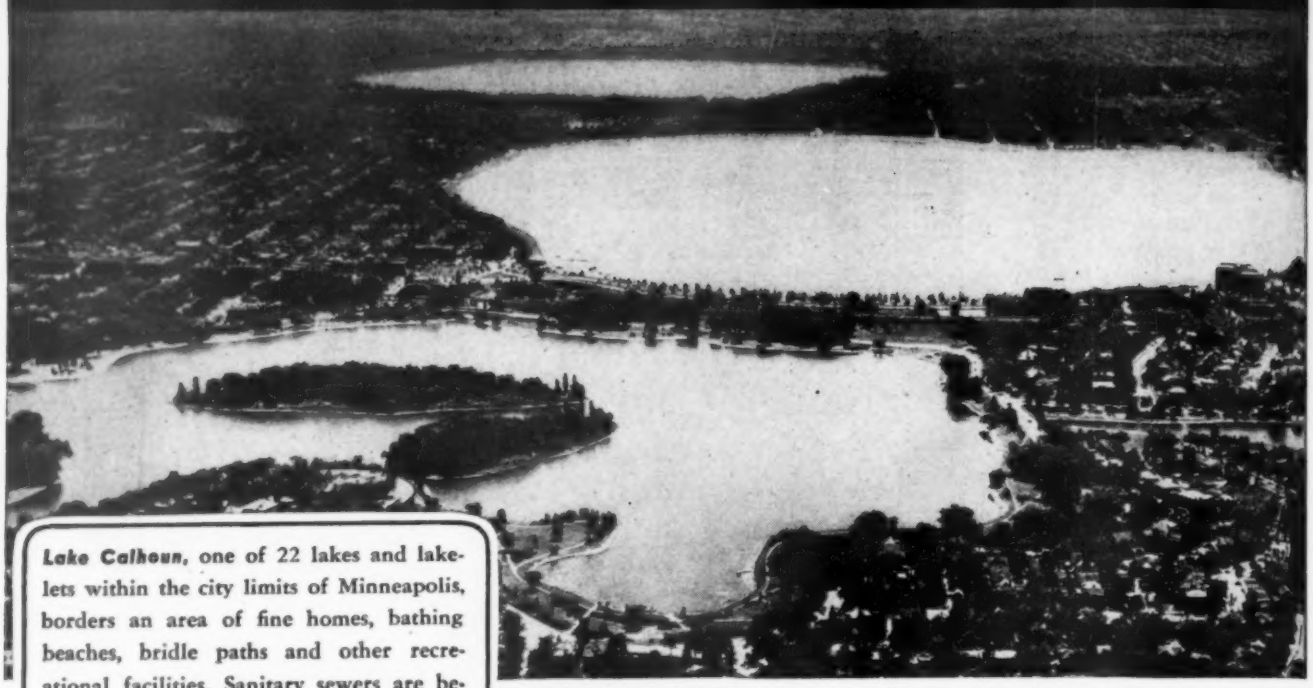
THE JAEGER MACHINE COMPANY

Main Office and Factory, Columbus 16, Ohio—Regional Offices at

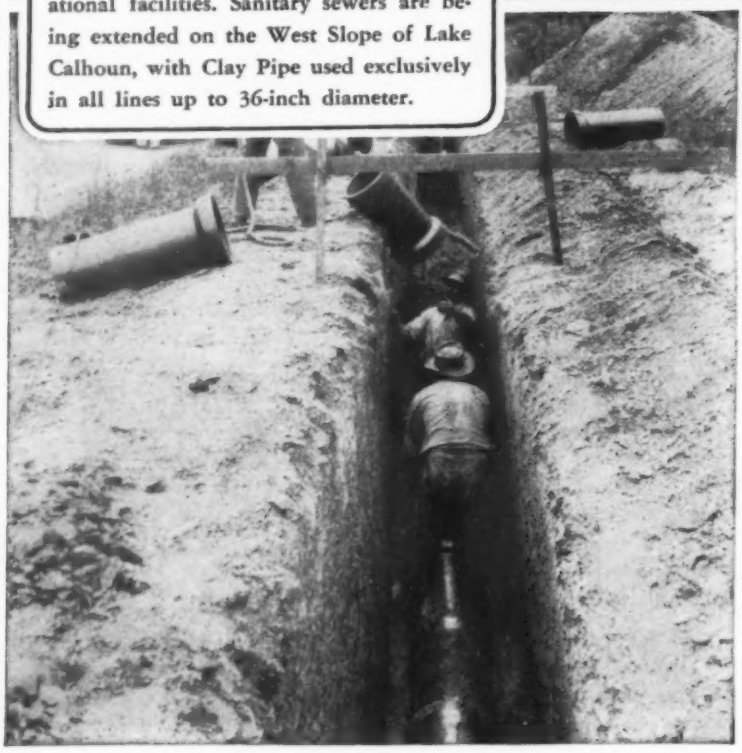
8 E. 48th Street, New York 17, N. Y. · 226 N. La Salle St., Chicago 1, Ill. · 235-8 Martin Bldg., Birmingham 1, Ala.

CLAY PIPE

GUARDS LAND VALUES — PUBLIC HEALTH AROUND BEAUTIFUL TWIN-CITY LAKES



Lake Calhoun, one of 22 lakes and lakelets within the city limits of Minneapolis, borders an area of fine homes, bathing beaches, bridle paths and other recreational facilities. Sanitary sewers are being extended on the West Slope of Lake Calhoun, with Clay Pipe used exclusively in all lines up to 36-inch diameter.



MINNEAPOLIS is increasing sanitary facilities with Clay Pipe in some of its finest residential sections. The installation of many miles of Vitrified Clay sewers in the famous Twin City is designed to protect the lakes from pollution for many decades. Land values of bordering residential lots, bathing beaches, playgrounds, etc. are greatly enhanced, now that the threat of water pollution is removed. Engineers who specified Clay Pipe for this modernization program wanted the *best!* They knew that high-quality, corrosion-proof Clay Pipe *never* wears out! It provides the greatest possible protection . . . assures long service and true economy.

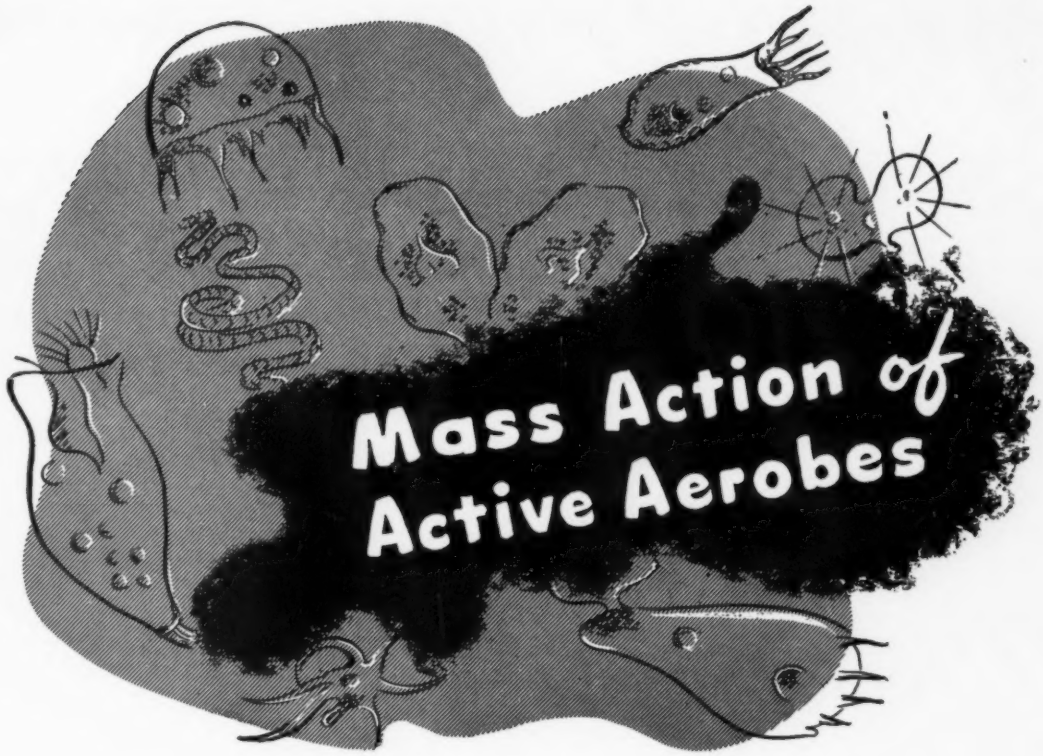
Careful Construction is important in any pipeline installation! Note the flat, level trench-bottom here . . . straight sidewalls . . . well-made joints . . . careful handling. Combine this sort of construction with the long-wearing properties of Clay Pipe itself, and you have a sewer line that gives decades of dependable service!

For information about Clay Pipe, write to the office nearest you.

NATIONAL CLAY PIPE MANUFACTURERS, INC.
571 Chamber of Commerce Bldg., Los Angeles 15, Calif.
522 First National Bank Bldg., Atlanta 3, Ga.
1105 Huntington Bank Bldg., Columbus 15, Ohio
111 W. Washington St., Chicago 2, Ill.

CLAY PIPE NEVER WEARS OUT! PIPE

C 947-1



Provided by DIRECT RECIRCULATION *through* ACCELO* FILTER

Mass action of active aerobes gives better reduction of organic matter in sewage and improves the final effluent. It is provided by the ACCELO FILTER system, which returns directly to the filter large quantities of the unsettled trickling filter effluent teeming with active aerobic bacteria, thus increasing to myriads the number of active aerobes in the filter.

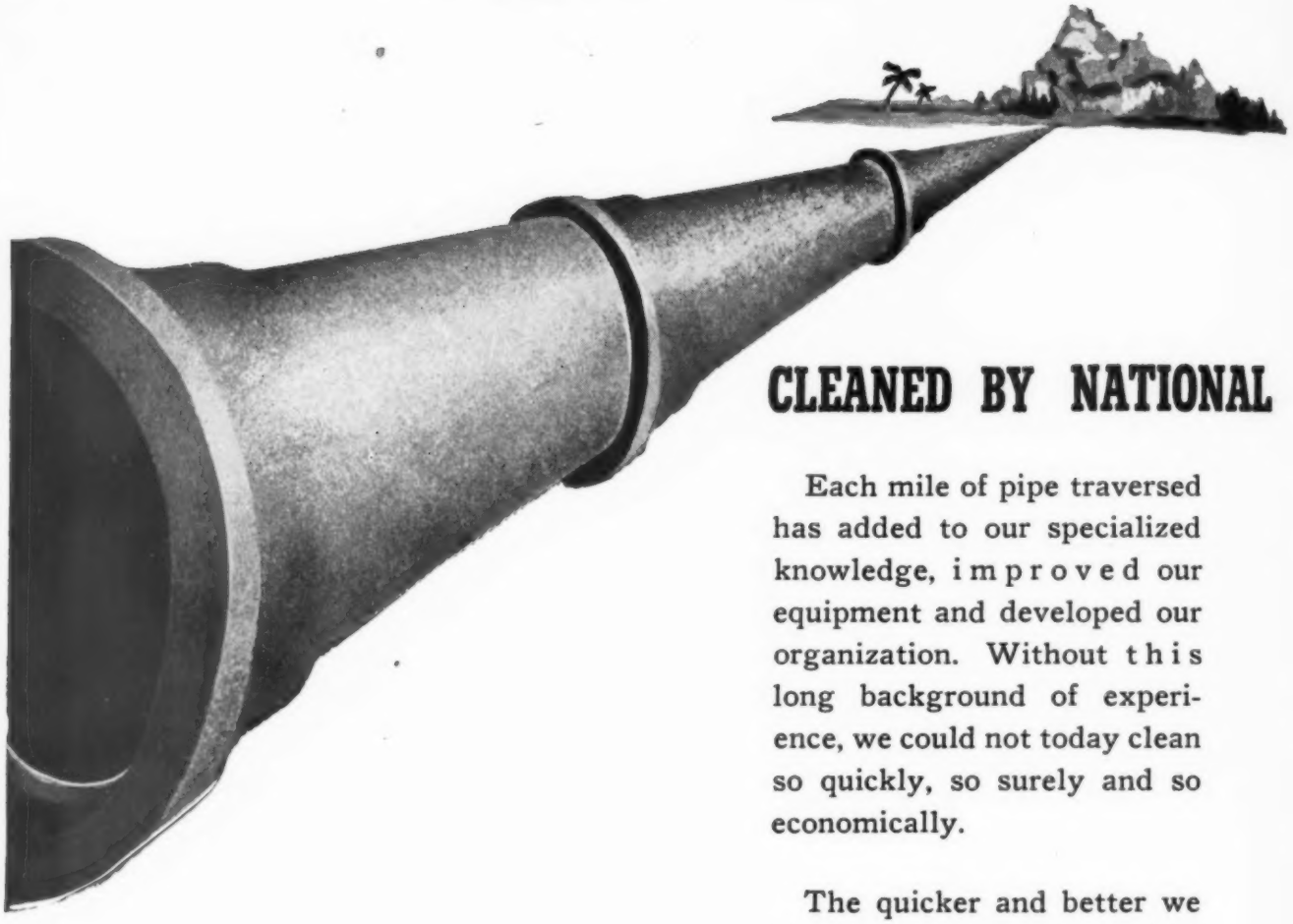
It is the UNSETTLED trickling filter effluent returned DIRECTLY to the filter that provides Mass Action of active aerobes. The aerobic bacteria in the unsettled effluent have been well supplied with oxygen and are in their most active state. Their span of life is from 3 to 5 minutes, and within that time they divide and multiply. To take advantage of this tremendous activity, the Accelo Filter system returns the unsettled effluent directly to the filter.

Write for authentic operation reports of Accelo Filter plants for proof of improved treatment results. INFILCO Inc., 325 West 25th Place, Chicago 16, Illinois.

*Trade-Mark Reg. U.S. Pat. Off.

IF YOU WANT TO KNOW — ASK INFILCO

36,960,000 FEET OF PIPE



CLEANED BY NATIONAL

Each mile of pipe traversed has added to our specialized knowledge, improved our equipment and developed our organization. Without this long background of experience, we could not today clean so quickly, so surely and so economically.

The quicker and better we clean, the less your services are interrupted, the less supplementary labor you supply and the more sure you are of satisfaction. We guarantee to restore any pipe to within at least 95% of its original capacity.

National "Know-How" Pays

BEFORE AFTER

NATIONAL WATER MAIN CLEANING COMPANY

50 CHURCH STREET, NEW YORK 7, N. Y.

ATLANTA..1221 Mortgage Guarantee Bldg.	LOS ANGELES.....448 South Hill Street	SALT LAKE CITY.149-151 W. 2nd South St.
BOSTON.....115 Peterboro Street	MEMPHIS.....822 Dermon Building	SAN FRANCISCO.....681 Market Street
CHICAGO.....205 West Wacker Drive	OMAHA.....3812 Costellar Street	MONTREAL.....2028 Union Avenue
HOUSTON.....2518 Grant Street	RICHMOND.....210 East Franklin Street	WACO.....P. O. Box 887
KANSAS CITY.....421 B.M.A. Building	ST. LOUIS.....7103 Dale Avenue	WINNIPEG.....576 Wall Street

HAVANA • MAYAGUEZ, PUERTO RICO • BOGOTA • CARACAS • MEXICO CITY

OMEGA
THE LAST WORD IN CHEMICAL FEEDERS

1. UNIVERSAL CHEMICAL FEEDER

The OMEGA Universal is a volumetric feeder famous for dependable operation. Large throat and orifice openings, with effective agitation at the outlet zone, permit handling lumpy material or fine powder without clogging. Successfully feeds alum, Ferrisul, Ferrifloc, lime, soda ash, clay, carbon, etc. The feeding rate is easily adjustable over a wide range, with capacity from 1 to 6,000 lbs. per hr.

2. ROTODIP SOLUTION FEEDER

For feeding water treating chemicals in solution — by gravity — the OMEGA Rotodip is ideal. It handles liquid alum, ferric chloride, acids, etc., with an accuracy within 1%. There are no valves, diaphragms or pumps — the unique shape of the rotating dippers insures precise, continuous delivery. Feeding rate is infinitely adjustable over a 100 to 1 range. Capacity up to 800 G.P.H.; can be furnished in multiple units for greater capacities.

3. LOSS-IN-WEIGHT TYPE GRAVIMETRIC FEEDER

The OMEGA Loss-In-Weight Gravimetric Feeder is the most accurate type of dry feeder made. It weighs, feeds and records with an accuracy of 1% or better. Feeder has hopper mounted on sensitive scales... feeding action is steady, and continuous, yet instantly responsive to manual adjustment or to proportioning devices. Automatic alarms safeguard proper operation. Capacity ½ to 5,000 lbs. per hr. Also used with OMEGA Slaker.

4. BELT-TYPE GRAVIMETRIC FEEDER AND LIME SLAKER

Material is weighed continuously on a short conveyor belt carried on sensitive scales... feeding by weight is exact, even when lime varies from fine to coarse. Handwheel adjustment gives an infinite number of feeding rates up to maximum. Automatic alarms to warn immediately of improper operation and complete recording devices can be furnished. The OMEGA lime slaker shown is fully insulated for most efficient high temperature operation. High speed mixers and attachments provide unusually rapid and complete slaking. Equipment includes thermostatic heat control and heat exchanger coils, with dust and vapor removal devices to prevent clogging. The OMEGA Slaker is designed to operate continuously... clinkers may be removed manually or mechanically without interrupting operation. Capacity from 175 to 10,000 lbs. per hr.

Write for Bulletins and complete information

OTHER OMEGA PRODUCTS • BUCKET ELEVATORS • LABORATORY STIRRERS • DUST COLLECTORS

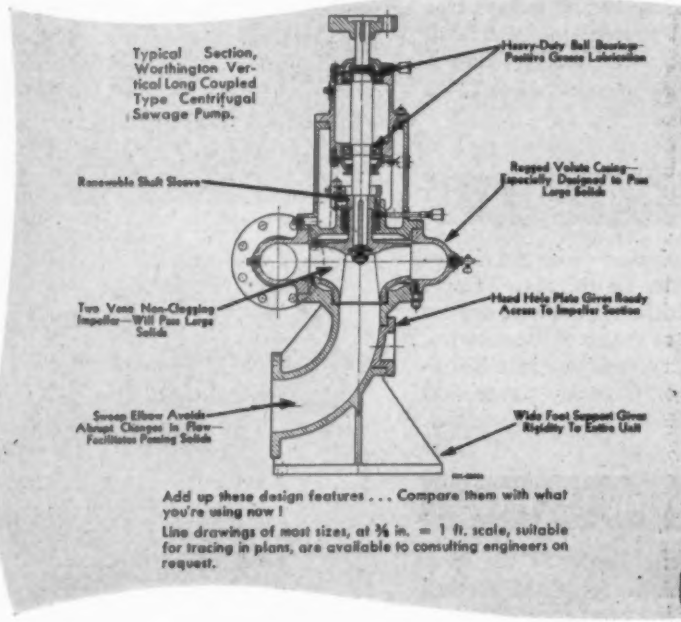
OMEGA MACHINE COMPANY

(Division of Builders Iron Foundry) 10 CODDING ST., PROVIDENCE 1, R. I.

Why COMPROMISE

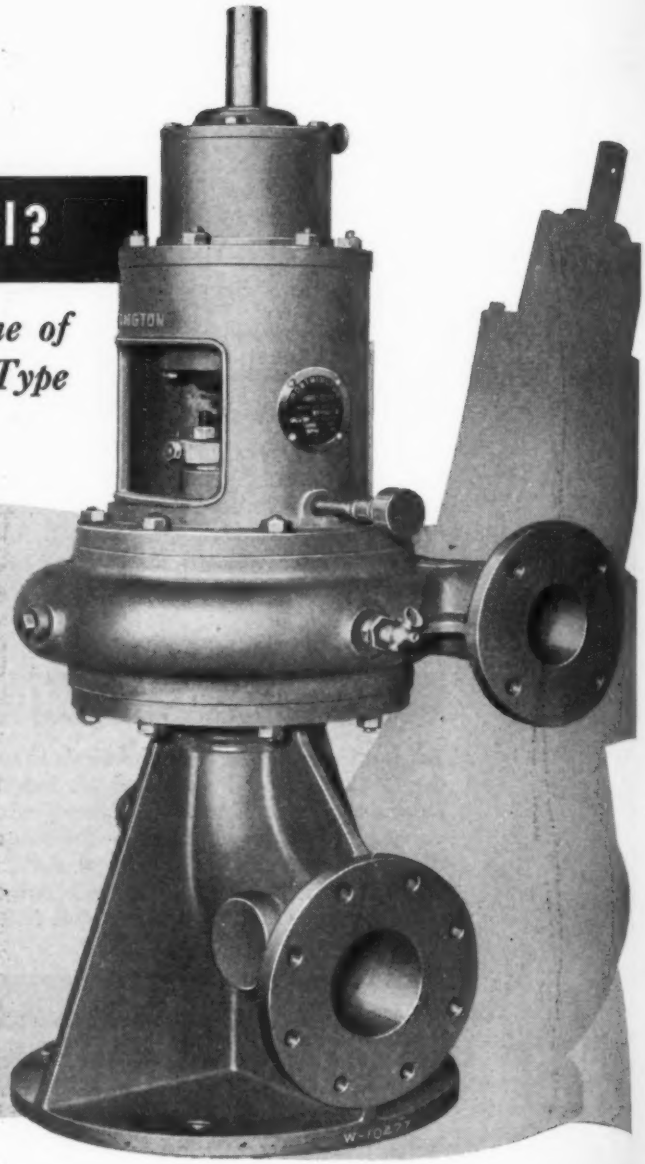
On Sewage Disposal?

In Worthington's New, Improved Line of Sewage Pumps You'll Find Exactly the Type and Size You Need


Typical Section, Worthington Vertical Long Coupled Type Centrifugal Sewage Pump.
Heavy-Duty Ball Bearings—Positive Grease Lubrication
Removable Shaft Sleeve
Rugged Volute Casing—Especially Designed to Pass Large Solids
Two Vane Non-Clogging Impeller—Will Pass Large Solids
Hand Hole Plate Gives Ready Access To Impeller Section
Sweep Elbow Avoids Abrupt Changes in Flow—Facilitates Passing Solids
Wide Foot Support Gives Rigidity To Entire Unit

Add up these design features . . . Compare them with what you're using now!

Line drawings of most sizes, at ⅜ in. = 1 ft. scale, suitable for tracing in plans, are available to consulting engineers on request.



Trying to force up-to-date performance out of outmoded waste-pumping equipment? Check on Worthington's latest line. Available in several models, and in sizes of 3, 4, 6, 8, 10, 12, 16 inches, and larger where required, these outstanding new developments offer you the *right* pump for your individual needs—not the "nearest thing to it". And their overall mechanical and hydraulic advancement—with simplified parts and greater interchangeability — assures always dependable performance, minimum maintenance and extra-long service life.

For further details proving *there's more worth in Worthington*, contact our nearest District Office. Or write to *Worthington Pump and Machinery Corporation, Harrison, New Jersey.*

MEMBER

MORE JOBS GO TO WORTHINGTON

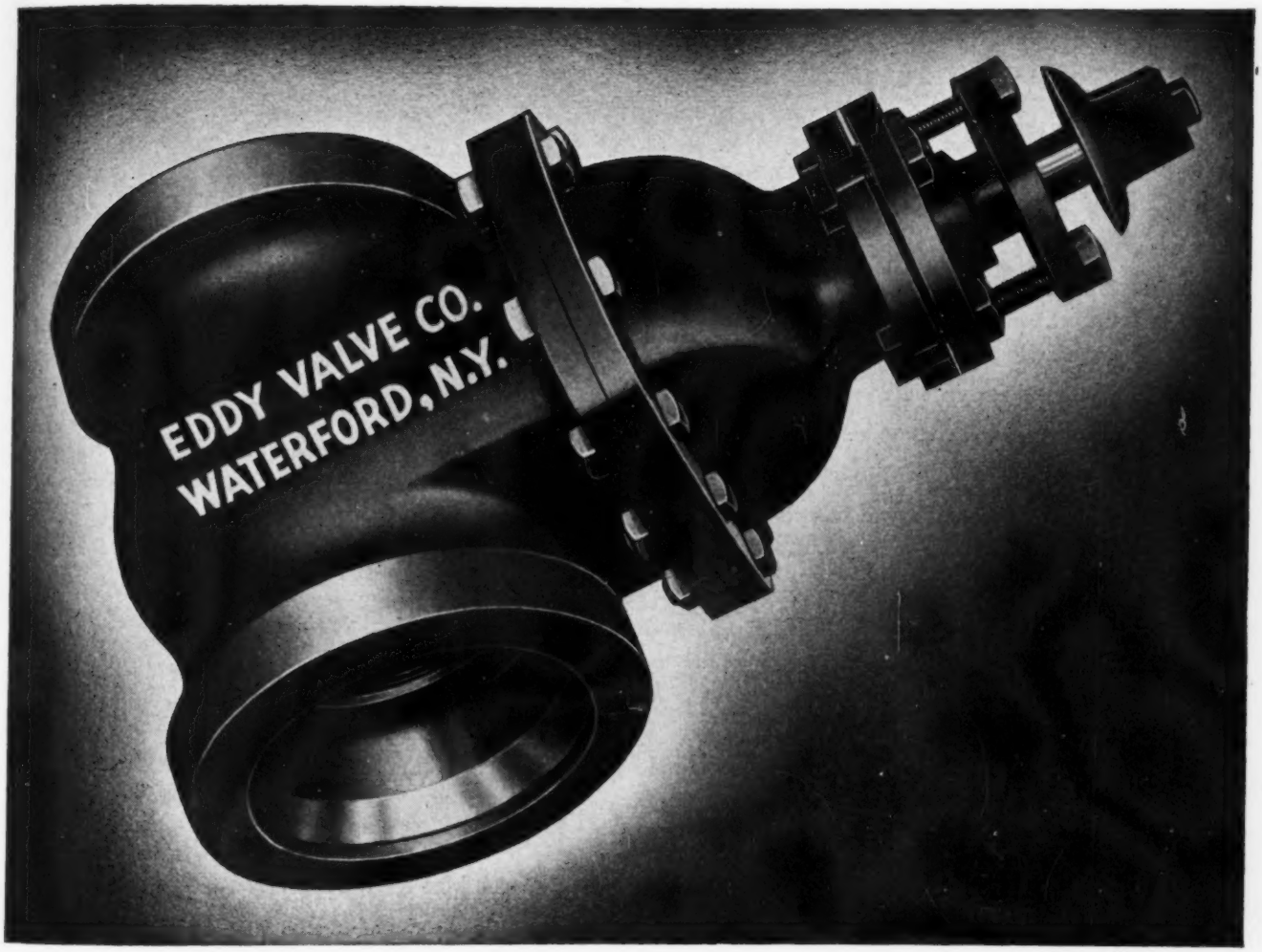
The Complete Line . . . The Top Engineering

Centrifugal Pumps . . . Diesel & Sewage Gas Engines . . . Dual-Fuel Engines . . . Turbines & Turbine-Generators . . . Gas Engine Compressors . . . Stationary Compressors . . . Water Softening, Filtering Equipment . . . Vertical Turbine Pumps . . . Water Meters . . . Power Transmission Equipment . . . Portable Compressors & Air Tools.

W7-2

WORTHINGTON

Bury it *and forget it!*



If you will think before buying a valve—you can eliminate thinking of it forever after. When you think of valves—think of the years of time and effort we have put into giving you a smooth-operating, trouble-free valve. Think of the progressive water works men who have relied on Eddy Valves for years—then specify and insist on getting Eddy Valves—You can bury them and forget them!

EDDY VALVE COMPANY • WATERFORD, NEW YORK

A subsidiary of James B. Clow & Sons

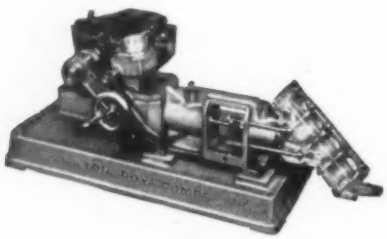
MILTON Roy PUMPS

NEW! Handbook and Catalog

This combined handbook and catalog will be of real help to you. It discusses electronics as applied to feed systems to obtain completely automatic volume control and avoid waste of costly chemicals. It describes Milton Roy Pumps with plastics valves designed especially to meter and pump hypochlorites, alum, soda ash and other treating chemicals.

It contains materials of construction suggestions for more than 150 chemicals; shows how the exclusive Milton Roy Step-Valve works; explains why this valve is non-clogging and self-cleaning; illustrates standard and special positive displacement pumps with manual as well as automatic controls, to pump as little as 1 pint per hour.

Ask for Catalog No. 146.



MILTON Roy COMPANY
1377 E. MERMAID AVE., CHESTNUT HILL, PHILA. 18, PA.

CUT

COSTS WITH

TENNESSEE CORPORATION
Ferri-floc
FERRIC SULPHATE
Atlanta, Georgia

Ferri-floc has cut costs in water purification plants from the Great Lakes to the Gulf and from the Atlantic Coast to the Rockies.

Ferri-floc is a partially hydrated ferric-sulphate that gives lower operating costs. Ferri-floc is readily soluble in coldest water—gives off no corrosive fumes in warmer water, making fans on the solution pot entirely unnecessary. It does not pass through a gummy stage going into solution—may be shipped in 100 lb. bags or bulk cars and stored in open bins for indefinite periods of time.

For complete information as to the many ways Ferri-floc will help lower your operating costs in the treatment of water, industrial wastes, sewage, and sludge conditioning write the Tennessee Corporation, Grant Building, Atlanta 1, Georgia, TODAY.

TENNESSEE CORPORATION
Atlanta, Georgia — Lockland, Ohio

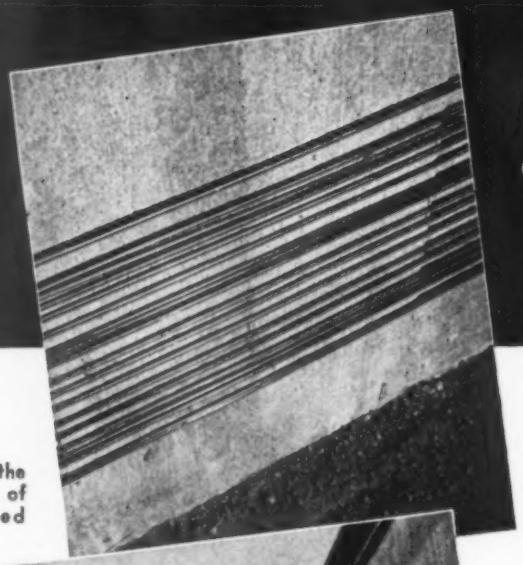
Original Woodcut by Lynd Ward

Activity in subdivision developments has stepped up the demand for smaller sizes of Super-deLavaud pipe. This centrifugally-cast pipe can be handled easily and laid speedily, in either 12-foot or 18-foot lengths with bell-and-spigot or standardized mechanical joints. Thanks to the Super-deLavaud centrifugal process, the pipe is uniform, tough and strong—all of which properties contribute substantially to the established long life of cast iron pipe.

U.S. cast iron PIPE

U. S. PIPE & FOUNDRY CO.
General Offices: Burlington, N. J.
Plants and Sales Offices throughout U.S.A.

Prestressed TANKS



A section of the first few turns of the prestressed wire in place.

Preloader prestressing high tensile strength wire on dome ring.

Preloader operator maintains control over wire tension.

THIRTY-FIVE MILES OF "PIANO" WIRE BALANCES THE LOAD ON TYPICAL WATER STORAGE TANK

Wire Prestressing with the automatic PRELOADER is being used on the 1,000,000 gallon water storage tank illustrated above and built for the U. S. Army Engineers at the Middleton, Pa., Air Depot by the Preload Corporation.

For a permanent army installation this prestressed tank illustrates a type of water storage which can virtually be "built and forgotten," as it will not require painting and will have little or no maintenance cost.

PRELOAD WIRE PRESTRESSING is a machine job making other methods obsolete. The wire winding machine eliminates guesswork. There is close control of the tension on the wire as it passes through the wire stressing mechanism which imposes a constant predetermined stress on the wire during application, unaffected by temperature variations during construction.

For circular tanks for water storage, filtration, or sewage disposal plants PRELOAD PRESTRESSED construction offers specific economies in original cost per gallon and substantial savings over other types of construction in concrete and steel quantities. Materials shortages do not affect construction of these tanks. They can be built immediately, using local materials and labor. We have high tensile strength wire and vertical prestressed reinforcing rods in stock.

Write for our literature and send us your tank problem

PRELOAD ENTERPRISES INC.

420 LEXINGTON AVE., NEW YORK, N. Y.

Designers and Builders of Prestressed Concrete Storage Tanks and Pressure Pipe
Prestressed Concrete Bridges and Cement Lining of Pipe in Place

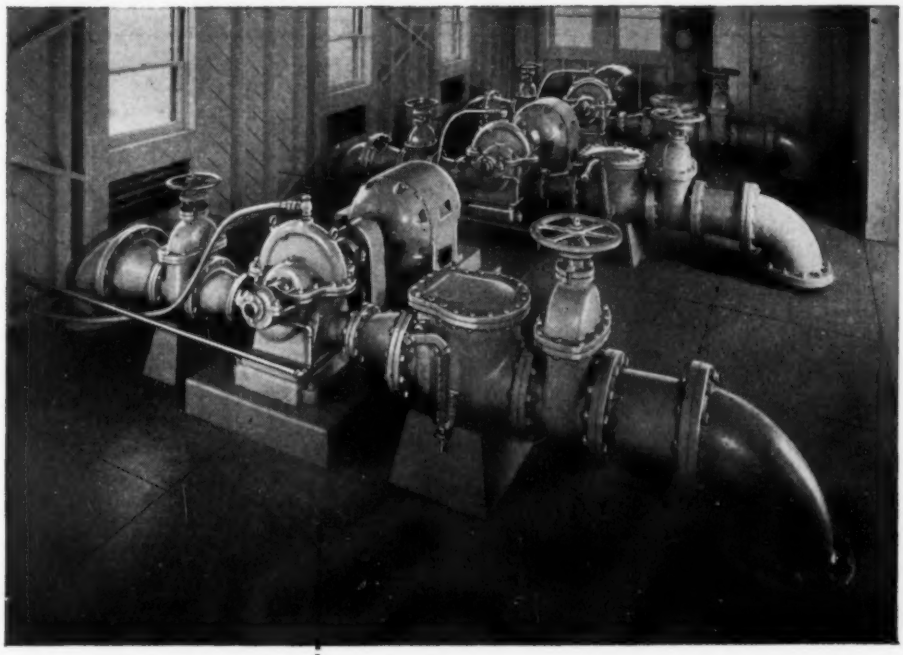
The Preload Corporation
New York—Boston—Washington

Preload Central Corporation
St. Louis—Chicago—Kansas City

PRELOAD TRADE MARK

Preload Pacific Corporation
San Francisco—Los Angeles

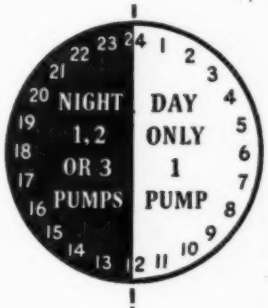
The Preload Co. of Canada, Ltd.
Montreal—Toronto—Halifax



IN SOUTH SAN FRANCISCO

Pumping costs are cut

BY DE LAVAL PUMPS WITH TIME CLOCK CONTROL



To assure the lowest possible operating costs, the California Water Service Co. has selected De Laval pumps for seventy-eight of its installations.

In the South San Francisco Station three of these pumps are operated by an automatic time clock system so designed that most of the pumping load is carried during the night at off peak power rates. A Bristol telemetering automatic control transmitter, located at the high level storage tank and connected over a leased telephone circuit, is tied in with a time clock control which operates one pump as required during the day; and one, two or three pumps at night.

The high sustained efficiency of De Laval Pumps keeps costs down year after year.

Atlanta • Boston • Charlotte
Chicago • Cleveland • Denver
Detroit • Helena • Houston
Kansas City • Washington, D.C.

DE LAVAL

Tulsa • Los Angeles • New York • New Orleans • Salt Lake City • Philadelphia • St. Paul Seattle • Pittsburgh • Rochester San Francisco • Winnipeg Toronto • Edmonton • Vancouver

DE LAVAL STEAM TURBINE COMPANY • TRENTON 2, N. J.

WW-3

TURBINES • HELICAL GEARS • WORM GEAR SPEED REDUCERS • CENTRIFUGAL PUMPS • CENTRIFUGAL BLOWERS AND COMPRESSORS • IMO OIL PUMPS

At the Convention Visit De Laval Booths Nos. 43 and 44

cloroben

THE MODERN WAY TO TREAT SEWAGE

Cloroben Treatment is the effective way to control odors and bacteria in sewage. Cloroben is harmless to personnel and easy to use.

Cloroben applied up-sewer reduces bacterial slime growth and dissolves greases. Internal cleaning and maintenance of sewer lines is held to a minimum.

Attack your gas, odor and slime problem with Cloroben.

In asking for prices and information describe your problem fully.

THE CLOROBEN CORPORATION

Jersey City 2, N. J.

It Wa… GO

90 T…

…ronymus
…eller Co—
…manship.
…ueller Co.'s
…dustries where
…egically placed
…ice to the trade.

Where Muell…
Business Sta…
in 1857

- Tapping an… Machines
- Tapping …
- Corporat…
- B…
- …
- …
- …
- …
- M…
- C… Fi…
- …
- …
- …
- Regu…
- Plumbing…

…and Factory, Decatur, Illinois

Chattanooga, Tennessee.

Factory, Los Angeles, California.

Factory, Sarnia, Ontario, Canada.

MUELLER CO.

MAIN OFFICE AND FACTORY ..... DECATUR, ILLINOIS

OTHER FACTORIES: *Los Angeles, Cal.; Chattanooga, Tenn.; Sarnia, Ont. Canada*

You are cordially invited to visit the

Calgon booth, No. 30, at the A.W.W.A.

Convention, San Francisco, July 20-25, 1947

*See for yourself how Calgon**

prevents scale... controls corrosion..

stabilizes lime-softened water...

eliminates "red water"

•

**T. M. Reg. U. S. Pat. Off.*

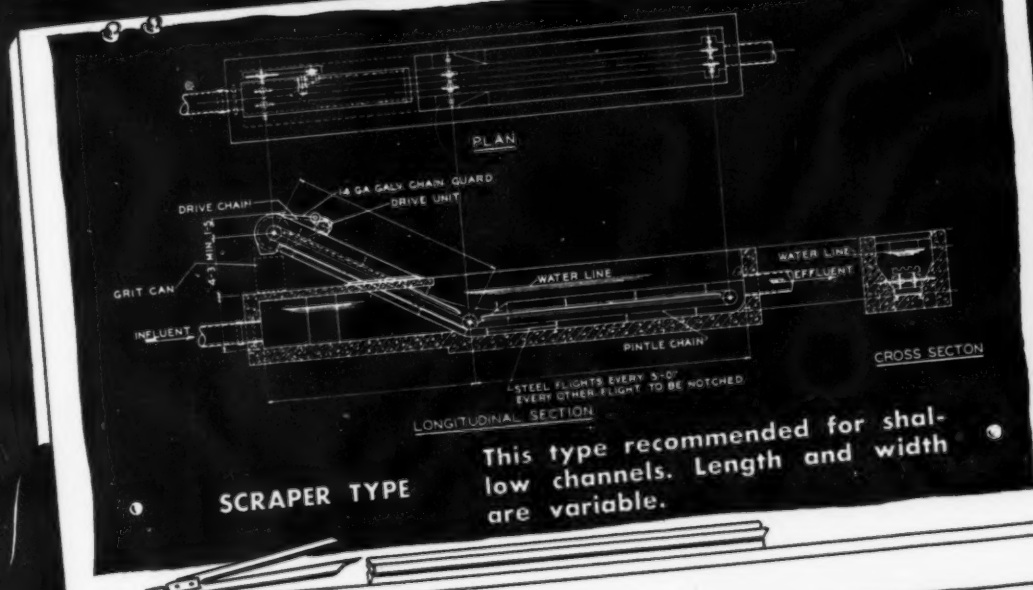
HAGAN
HALL
BUROMIN
CALGON

calgon, inc.

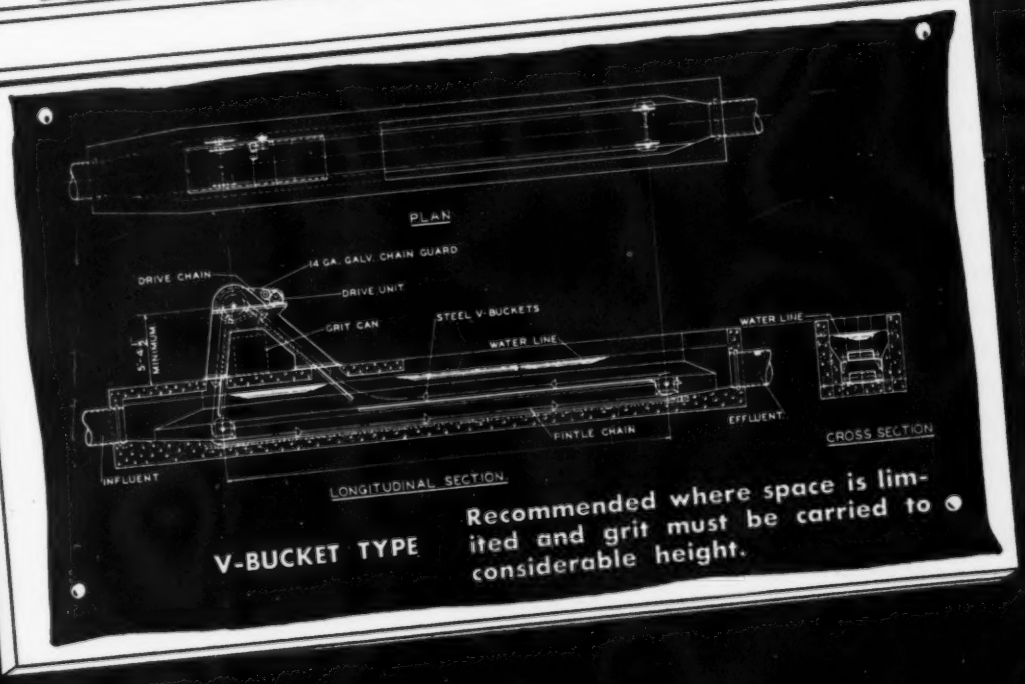
A SUBSIDIARY OF
HAGAN CORPORATION

HAGAN BUILDING
PITTSBURGH 30, PA.

Jeffrey GRIT COLLECTORS



SCRAPER TYPE This type recommended for shallow channels. Length and width are variable.



V-BUCKET TYPE Recommended where space is limited and grit must be carried to considerable height.

PLANNED TO MEET REQUIREMENTS

JEFFREY

ESTABLISHED 1877

JM

Contaminated Water Supplies?

GET % PROPORTIONEERS %

CHEM-O-FEEDER

The discovery of harmful organisms and disease germs in your water supply is something to get excited about . . . destroy them by hypochlorination with %Proportioneers% Heavy Duty Chem-O-Feeder — the modern way to protect the health of your community. There's no risk of dangerous undertreatment or the disagreeable taste resulting from wasteful overtreatment. By simply turning a knob, the chemical feeding rate may be instantly adjusted while the pump is operating . . . up to 7 g.p.h. can be fed with extreme precision.

Sterilization of water supplies becomes entirely automatic with the Chem-O-Feeder cross-connected to the starting switch of the main pump motor. No skilled help is required as there is none of the danger that goes with using deadly chlorine gas. The chemical being fed shows plainly in the "See-Thru" plastic head and the action of the check valves and diaphragms is clearly visible. In addition to handling hypochlorite solution, the Heavy Duty Chem-O-Feeder successfully feeds all other water treating chemicals — soda ash, lime slurry, aqua ammonia, activated carbon, sulphates, ferric chloride, polyphosphates, etc.

Heavy Duty Chem-O-Feeder

For help with your chemical feeding problems write %Proportioneers, Inc.%.

Ask for Bulletin SAN-2.

% PROPORTIONEERS, INC. %

"Chemical Feeder Headquarters"

WRITE TO %PROPORTIONEERS, INC.% 9 CODDING ST., PROVIDENCE 1, RHODE ISLAND

"HTH has no equal!"
—Everett Harris, First Engineer, Moberly Water Dept., Moberly, Mo.
"HTH sterilizes more thoroughly!"
—George E. Regester, Jr., Engineer and Supt. of the Borough of Kennett Square, Pa.
"We play safe with HTH!"
—Three Rivers Filtration Plant, Fort Wayne, Ind.
SANITATION
HTH
"I wouldn't be without HTH!"
—O. F. Stompler, Supt., Langhorne Spring Water Co., Langhorne, Pa.
"HTH is low in cost...easy to apply!"
—Joseph E. Moore, Supt., Burlington City Water Works, Burlington, Vt.

IT'S EASY TO UNDERSTAND why prominent water works officials praise Sanitation HTH. They use it—and prefer it—for regular or emergency hypo-chlorination of water . . controlling algae . . cleaning filtration screens . . treating coagulation basins and pipelines . . . decontaminating broken mains . . . sterilizing new or extended mains . . . all-around sanitation. Write for Mathieson's 80-page booklet—"Hypo-Chlorination of Water." In addition to describing all standard sanitation practices, it shows how to employ Sanitation HTH in many unusual ways. Get your copy; it's free to water works men. THE MATHIESON ALKALI WORKS (INC.), 60 East 42nd Street, New York 17, N. Y.

Mathieson
SANITATION HTH

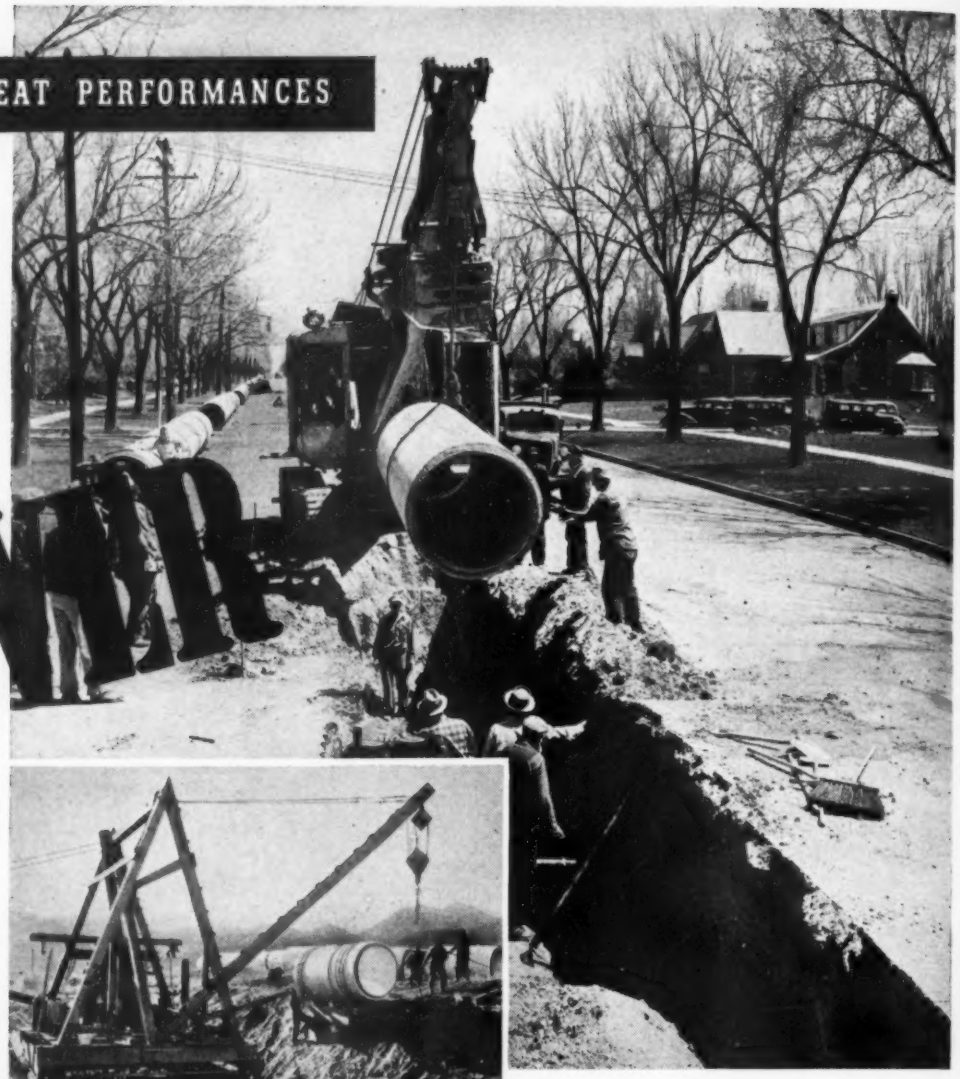
Sanitation HTH . . . Liquid Chlorine . . . Chlorine Dioxide . . . PH-Plus (Fused Alkali) . . . Caustic Soda Soda Ash . . . Bicarbonate of Soda . . . Ammonia, Anhydrous & Aqua . . . Dry Ice . . . Carbonic Gas Sodium Chlorite Products . . . Sodium Methylate

SANITATION HTH *is available in cases of nine 5-lb. cans and in 100-lb. drums.*

LOCK JOINT REPEAT PERFORMANCES

DENVER

13 JOBS SINCE 1920



1940—Above: Installing 48" pipe through center of street in residential area.

1921—Left: Installing pipe with old type wooden derrick astride ditch.

To meet the enormous demands of increasing population and expanding industry, Denver has steadily extended its water supply system. Since 1920 Lock Joint Pipe Company has been awarded 13 major water works contracts totalling approximately 90 miles of Reinforced Concrete Pressure Pipe. Such repeat orders, not only for Denver but for many other key cities, are convincing evidence of the incomparable quality of Lock Joint Reinforced Concrete Pressure Pipe.

The life expectancy of Lock Joint Reinforced Concrete Pressure Pipe has been rated at better than 100 years. During this life span Lock Joint Pipe will retain its characteristic high qualities: immense structural strength, permanent high carrying capacity, low maintenance cost and unfailing service.

SCOPE OF SERVICES—*Lock Joint Pipe Company specializes in the manufacture and installation of Reinforced Concrete Pressure Pipe for Water Supply and Distribution Mains in a wide range of diameters as well as Concrete Pipe of all types for Sanitary Sewers, Storm Drains, Culverts and Subaqueous Lines.*

For future projects, large or small, specify Lock Joint Pipe.

...zen-Williams Hydraulic Slide Rule will ...e sent upon request with our compliments.

★

LOCK JOINT PIPE COMPANY

Established 1905

P. O. Box 269, East Orange, N. J.

Pressure Pipe Plant: Wharton, N. J. • Sewer Plant: Kenilworth, N. J.

BRANCH OFFICES: Denver, Colo. • Chicago, Ill. Kansas City, Mo. • Rock Island, Ill. • Joplin, Mo. Valley Park, Mo. • Cleveland, Ohio • Hartford, Conn. Navarre, Ohio

WATER & SEWAGE WORKS

E. S. GILLETTE, Publisher
22 W. Maple St., Chicago 10, Ill.

L. H. ENSLOW, Editor
155 East 44th Street, New York 17, N. Y.

COMING!

This Month's Cover

The cover picture on this issue is San Francisco's "Water Temple," which may be seen this month by those attending the conventions of the American Water Works Assn. and the Sewage Works Federation, concurrently held in San Francisco.

This beautiful structure was erected at the San Francisco end of the famed 149.6 mile long Hetch Hetchy Aqueduct, which on October 28, 1934, brought into the city a new and abundant supply of soft pure mountain water.

The classic design of H. M. Michelsen was inspired by the Temple of Vesta at Tivoli. It was erected solely to symbolize the completion of a work of great importance to San Francisco. The inscription which runs around the entablature above the columns reads—

"I will give waters in the wilderness and rivers in the desert, to give drink to my people."—Isaiah, 43:20.

Fluoride Removal From Mine Water

Is featured in a water treatment plant which produces potable water from mine water high in fluoride content. It is probably the largest plant of its kind. This modern and unique plant is described and its accomplishments set forth by—

ROBT. WAMSLEY and W. E. JONES,
Climax Molybdenum Co., Climax, Colo.

[It is regretted that this article, announced previously, has been so long delayed.]

The Operation of Small Filtration Plants

Is the subject of a new series of short articles dealing with the operation and maintenance of small filtration plants by an author who has had considerable experience in filter plant and pumping station operation. The first of this new series is devoted to the part played by the laboratory in the small filter plants, the second to pumps and motors, with others to follow. The author—

A. E. CLARK, Gen'l Mgr.,
Nashville Suburban Utilities Dist., Nashville, Tenn.

Treatment of Wastes Containing Toxic Metals and Cyanides

Is an article describing the treatment plant and process employed by an important manufacturer in the successful treatment of electroplating wastes containing toxic metals and deadly cyanides. The plant and process are the outcome of seven years of study of the problem by Talon, Inc., of Meadville, Pa., under the direction of the author—

GEORGE E. BARNES, Consulting Engr.,
Head, Dept. of Civil Engr., Case Institute of Technology, Cleveland, Ohio.

Are Your Customers Water Conscious?

Is the question raised and discussed by the small town water superintendent interested in good relations with the public and in particular with the water department's customers. He gives some experiences and well chosen pointers which should be helpful to the small town water superintendent. The author is—

ERNEST J. BEAR,
Supt. of Water & Sewerage, Livingston, N. J.

With Regrets!

We find it necessary to hold out the report of the **Joint Meeting of the N. Y. State and New England Sewage Works Associations,** prepared for this issue. Because of the length of this report, which is considered justified on the score of the size and excellence of this joint meeting, it will be run in full in our August issue.

VOL. 94, NO. 7 — JULY, 1947

CONTENTS

A Guest Editorial ..... Forward Insert
By Wendell R. La Due, President, The American Water Works Association

Today's Costs of Water Main Extensions 229
By Fred J. Reny, Portland, Maine

Storage on the Distribution System 233
By Charles B. Burdick, Chicago, Illinois

The A-B-C of Depreciation 237
By John H. Murdoch, Jr., New York, New York

Hydraulics for the Practical Water Works Man, Part X ... 245
By Robert W. Angus, Toronto, Canada

Mechanical Sewer Cleaners Simplify Sewer Maintenance.. 249
By Reuben F. Brown, Los Angeles, California

Determining the Efficiency of Cooling Towers, Spray Ponds, or Similar Cooling Devices 252
By W. F. Schaphorst, Newark, New Jersey

The Handling and Use of Chlorine 253
From "The Chlorine Manual" of The Chlorine Institute

Michigan Sewage Assn. Features Industrial Wastes on Program 259

Meetings Scheduled .....Ad. Pages 108, 109

"Here and There" with Doc Symons .....Ad. Page 110

Manufacturers' and Equipment News .....Ad. Page 117

Literature & Catalog Reviews .....Ad. Page 130

Associate Editor
GEORGE E. SYMONS, Ph.D

Editorial Associates	Adv. Editor
J. R. BAYLIS	H. J. CONWAY
A. M. RAWN	Make-Up Editor
H. A. FABER	L. D. SANDERS

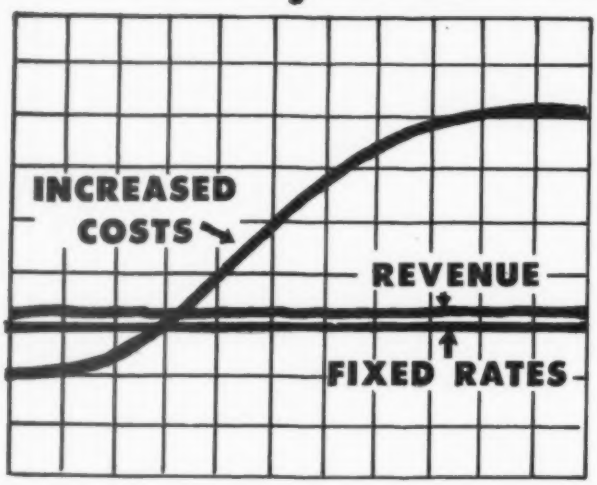
OFFICE OF PUBLICATION
22 W. Maple St., Chicago 10, Ill.

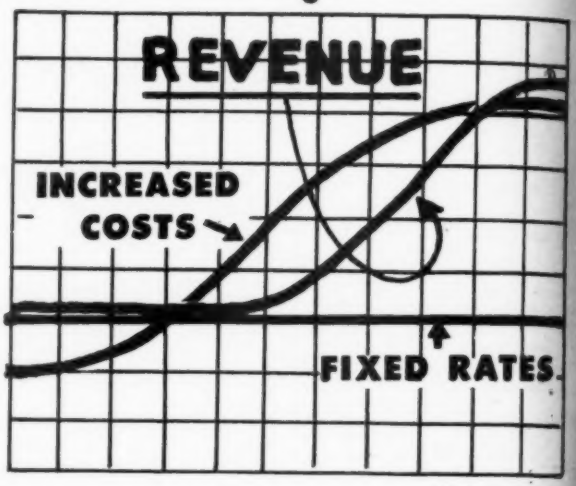
H. P. GILLETTE, Pres.; E. S. GILLETTE, Vice Pres.; L. H. ENSLOW, Vice Pres.
New York Office...J. M. Angell, Jr., Mgr., 155 East 44th Street
Chicago Office.....R. T. Wilson and D. R. Maggart, 22 W. Maple Street
Cleveland Office...Lee B. McMahon, Mgr., Leader Building
Los Angeles Office. Don Harway, Rep., 1709 W. Eighth Street

WATER AND SEWAGE WORKS is a monthly publication. Single Copies, 25c; Subscription Rates, U. S. and Canada, $2 per year; Foreign, $3.

WELL LAID PLANS MAY CHANGE

this picture..... to this!

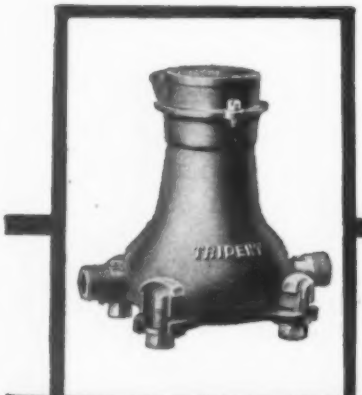




by reducing unaccounted-for water

For instance — a city in Wisconsin realized that with meters recording only 74% of the water pumped, a great deal of revenue was running to waste. Through research, experiment, planning and hard work, registration and revenues gradually increased until sufficient reserves had been accumulated to permit a *reduction* in water rates of 6.6%. At last report a registration of 92.78% had been reached.

True, your town may never be able to REDUCE your water rates — but you CAN probably materially increase your revenue by reducing UNACCOUNTED-FOR WATER, as this and many other towns and cities have done, through a systematic program of meter inspection and repair. Accounting for 85% of the water you pump is not too much to expect when leakage is properly controlled and domestic meters register 90% at ¼ gpm. For assistance in putting such a program into operation, see your Trident representative.



NEPTUNE METER COMPANY • 50 West 50th Street • NEW YORK 20, N. Y.

Branch Offices in Chicago, San Francisco, Los Angeles, Portland, Ore., Denver, Dallas, Kansas City, Louisville, Atlanta, Boston.

NEPTUNE METERS, LTD., Long Branch, Ont., Canada

175

. . . . *"It is only by labor*
that thought can be made healthy;
and only by thought
that labor can be made happy;
and the two cannot be separated
with impunity."—John Ruskin.

This Job of Ours

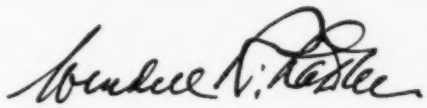
A Guest Editorial
by
Wendell R. La Due

SAMUEL M. VAUCLAIN, in referring to the dignity of man's work, once made the following statement:

"The hard thing in life is not to make the money needed for happiness, but to find the job you can do best. . . . Make it your friend. Do not cheat or skimp it; be loyal and zealous and your job will reward you with every joy and friendship."

Not long ago an old negro driver was perched upon the seat of a trash wagon, belaboring his mule and referring, among other things, to the mule's ancestry. A prominent white man of the community, upon witnessing the procedure, walked up and said, "Sam, don't you know that is no way to handle a *mule;* get down off that seat and talk to him." The old negro got down slowly, sauntered up to the head of the mule and stood rather undecidedly. "Go ahead, talk to him." The old negro sidled closer to the mule, which stood with watchful eye, and said in a doubting but friendly voice, "Big boy, I's from Memphis; where is you all from?"

This story may be termed "the beginning of a mutual understanding," and its application, particularly to our job of public contact, will unfold as we proceed.



President
The American Water Works Association.

Basically, just what is our job of Public Relations? The dictionary definition does not suffice, since in this case it is difficult to describe and include the complexities injected into a problem so susceptible to the human element. The word "relations" is not in itself enough, for we must somehow remember that we are talking of intimate contacts, services and acquaintances, as well as casual observations and incidental experiences. Shall we observe for serious retention the thought that any industry that performs services of an economic and social value for large numbers of people has for one of its *major* service projects the problem of public relations. As operators of water utilities, public and private, we are in a service category along with a host of businesses, which cover the scale from the bootblack to the gas, the electric and the water utility.

To analyze our position will require an "about-face" to a study in altruistic psychology—putting ourselves in the other fellow's place, remembering that *to the "other fellow" we are the "other fellow."* By self-analysis, how do *we* react to the same situations developed by ourselves in other public service businesses? In other words, by "self-analysis" we determine our own reactions to strictly human situations. Candidly, what do *we* expect of the gas, the electric, the telephone utility? What do *we* expect of our bootblack, our grocer, our tailor, our druggist and our barber?

The analogy is plain. Each man in his own business is an exponent of public relations, from the simple approach of the bootblack to the more complex, studied approach of the electric or gas utility. Yet, behind it all in this job of ours there is one prime factor which enters into all public relations—the element of human contact, acquaintanceship and resulting confidence.

No one can deny that to be recognized by his bootblack, his grocer and his merchandiser creates a feeling of immediate goodwill and confidence. We get to *know* the man, we *feel* we know his wares, we *grant* his integrity, we *take* his word.

We may say that such intimate contact is not possible or is at least reduced as the complexity of the organization is increased. The point is well taken yet the fundamental idea of confidence in whom you are dealing remains—the concept of confidence through acquaintanceship. We now begin to realize the application of the story of the old negro and his mule. Very little was accomplished toward mutual understanding *until* acquaintanceship and confidence were established. This is basic in our own private dealings with others. Why is it not applicable in this job of ours? We must become acquainted with our public, although it is recognized that the size of each water utility fixes the pattern to be followed in gaining that end.

Some of the Manager's Problems

Let us, for the moment, confine our remarks to the superintendent's or manager's problems and role in this human drama. Unquestionably, his is a difficult task and one for which unfortunately few managers are by nature equipped. Yet, he must face it and master it if he is to succeed in having public confidence. He will soon learn the value of acquaintanceship. To be known by many, and favorably so, is a real asset to

any business man. We can really feel sorry for the superintendent who retires to his office, fails to meet his public, and thereby fails to sell himself and through himself his company or department and its services. If many people know him in all walks of life, his company will not lack a champion when it appears to be on the spot, wants to expand, or tries to explain away an obnoxious taste.

We may say we do not have the time it takes to develop such contacts. The statement is both true and false in its implications—it is true that such things do take time but false that we cannot find the time. In fact, no problem in our business is as worthy of the time required as is the problem of public contacts.

An illustration is in order. Every water utility is well organized to repair a simple broken main. It receives the call, a truck is dispatched, equipped with necessary tools and trained men. The public in the affected area is notified of the cessation of service, valves are closed, the repair is made, valves are opened and *service* is restored—all as a matter of routine, as a matter of organized public service.

Now let me cite an instance of another sort of disrupted service. A man comes to our office with a complaint. To *his* mind, it is a very important matter or he would not take *his* time to come to *our* office to protest what *he* thinks is *our* fault. If we are smart, he will be given all the time he requires to tell his story. We must be friendly and attentive. Are we not confronted with a "break" in public relations in his neighborhood? If it is not repaired, the whole neighborhood will become involved and "public relation service" will not be restored so easily. Can we afford to take the time? By all means, we *must* or we will take more time if we should be so foolish as to allow the break to enlarge. Is this important to our job? People are as much our vital concern as is our plant.

Apropos to this situation, Paul T. Babson of Standard & Poor's Corporation once wrote:

What Is a Customer?

"A customer is not dependent on us
—we are dependent on him.
A customer is not an interruption of our work
—he is the purpose of it.
A customer is not an outsider to our business
—he is part of it.
A customer is not someone to argue or match wits with.
A customer is a person and not a statistic. He has feelings, emotions, biases, prejudices and wants. It is our job to satisfy him."

Public relations men are peculiar types of individuals. If we know their essential characteristics, we can strive to emulate them. Such a man must have a liking for people—all kinds of people, from the laborer to the large corporation executive. He must have brotherly love in his heart, the wisdom of Solomon in his head, and the "milk of human kindness" all over his face, more especially in his eye.

Where Does AWWA Fit In?

I realize I may have been using rather homely examples, but the problem really calls for human examples of the "every-day" sort. We must now ask ourselves, "How does our American Water Works Association fit into this picture?" Before proceeding, I shall risk the repetition of one sentence, namely, "Any industry that performs services of an economic and social value for large numbers of people has for one of its *major* service projects the problem of public relations." As water works men we recognize that problem. As members of the Association we can reasonably expect our Association to assist us in that problem if *we* are willing and ready to help ourselves.

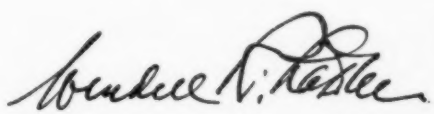
The problem is very personal, as we must admit. Our Association can promote standards of competency among its members and such an activity may be considered highly proper for it to do. We cannot, however, permit ourselves to be guilty of requiring the promulgation of rigid and fixed standards in an attempt to write a formula for an item which we recognize as changeable, mutable and involved with so complex an unknown variable—human nature. As Charles F. Kettering recently remarked: "We have found that it doesn't pay to ordain things because we don't *know* enough to mastermind anything." Much rather should we, as professional men, engaged in the oldest and most indispensable of public utilities, bend our efforts toward fixing our aims, setting our objectives and establishing our purposes; granting to each water works man that *he* has the desire to use *his* intelligence to obtain those objectives by his own individual solution, using such aid as the Association may be able to give, suggest or direct.

The development of activity in public relations by the American Water Works Association, now in the process of releasing, will contain much helpful material—a basic statement of the problem, an outline of objectives, minimum standards of approach, and, best of all, actual case histories of living persons who have met and solved the problem in their communities. We are all intrigued by the experiences of those whom we know and respect. Such experiences will be alive, growing and contemporary.

For years the Association has taken the lead and held it in material things—specifications for pipe, valves, meters, hydrants, etc., manuals of practice. It has recently developed a concept of social responsibility in its "Code of Ethics" one declaration of which reads, "I shall by all legitimate and reasonable means strive to improve the public appreciation of the service rendered by myself and my associates, to the end that employment in the water supply field is recognized by all as a legitimate and life-time career for well-trained and industrious citizens." A true public relation declaration of our desire to get along and to live together with other people.

This, then, is our job. To accomplish it, we must advise, inform and acquaint the public of our utility's contributions to the betterment of every day living and of the various ways in which these contributions are made. We must secure sympathetic public understanding of our community essentiality by giving our fine points, basic facts and figures, our accepted duties and responsibilities, our processes, our results, our aims, our goals—in other words, promulgation of a well-planned program of consistent, truthful information, directed to the people we serve.

If we are to hope for recognition, we must realize clearly our function in society and pursue it diligently in the promotion of understanding, acquaintanceship and confidence—these being the foundation stones of good-will.



of
cia-
and

Our
ncy
con-
ver,
lga-
rite
ble,
own
re-
pay
nas-
pro-
dis-
ward
ning
that
hose
such
t or

the
cess
l—a
ives,
ctual
olved
gued
pect.
tem-

held
lves,
s re-
n its
s, "I
ve to
dered
ploy-
as a
d in-
ation
with

must
lity's
g and
s are
tand-
r fine
s and
aims,
well-
ation,

ealize
gently
ceship
nes of

WATER & SEWAGE WORKS

VOL. 94, NO. 7 JULY, 1947

A Gillette Publication

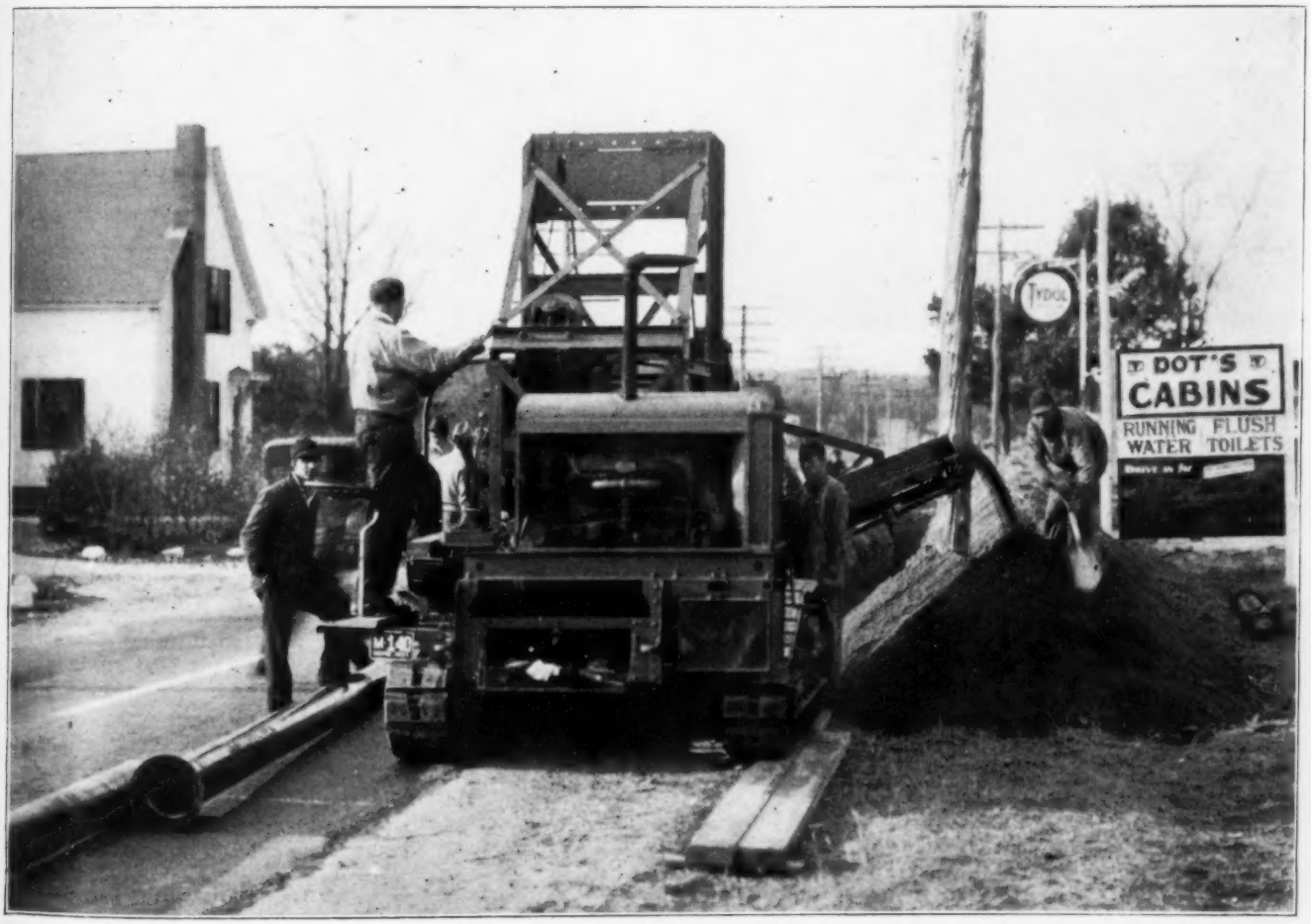
TODAY'S COSTS OF WATER MAIN EXTENSIONS*

Wherein a Study of 1946 Costs Reveals Yesterday's Methods Outmoded by Modern Machines

By FRED J. RENY
Treasurer and Manager
PORTLAND WATER DISTR.
PORTLAND, ME.

SINCE the early stages of World War II the water utilities operator has found conditions so changed because of the lack of manpower that he has been forced to adopt other methods to construct and maintain the water works. When man power had been available to do the work in the streets, it was easy to figure construction costs, and the estimates could be depended upon to be fairly in line with actual costs of doing the job.

*An article developed at the request of the editors of *Water & Sewage Works* as the result of impromptu remarks made by the author before the Maine Water Utilities Association.



Barber-Green Trencher at Work

We have dug the trench and installed as much as 1500 ft. of pipe in one day with this machine in soft digging

At the end of the war, the demand for water works construction became intensified because of the housing shortage and war-delayed improvements.

In spite of the aid of the United States Employment Service and other agencies, labor was practically impossible to secure for heavy street work because of the low scale of wages paid by the utilities, and also because of the heavy nature of the work.

It is the duty of the water utility to furnish water service, and the lack of labor or material is not considered as an excuse for not providing this service when the request is reasonable.

As in the case of the Portland Water District, many utilities found themselves in this position, and after efforts to secure labor had failed, decided to hire a contractor to do the work of excavation and backfill and to use their own men to install the mains and services.

The Author
(Chairman New England Sect. AWWA)

Water Takers Dig Trench To Get Service

Owing to the heavy demand for new water services and renewals, it was very difficult to install them as fast as they were needed. As a result, in several instances a number of new water takers, who had requested service where there was no water main, dug the trench themselves and we repaid them on our basis for this work. We made a minimum payment for this at 50c per foot for trench and backfill, and the utility furnished and laid the pipe and fittings and also the labor of service installation. If the trench was in ledge, we secured bids from several contractors for the ledge excavation and backfill. Our best quotation during the season was $4.00 per foot for ledge and 75c per foot for dirt trench. In some cases we had to haul gravel to fill the trench where the black top had been dug by the trencher.

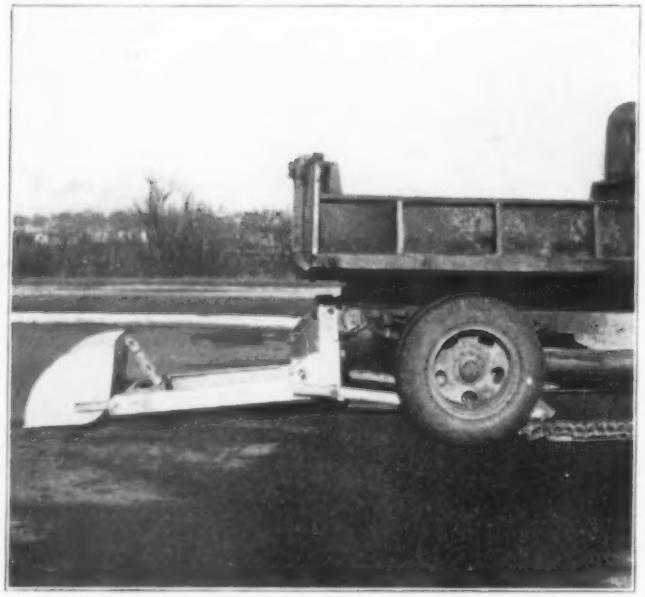
Some Cost Comparisons

It is interesting to note the comparison of costs of work performed by contractor and trencher **and our** own estimates, honestly and sincerely made by our engineers where work was estimated to be done by our organization.

For instance, on one extension of 844 ft. of 6 in. pipe, of which 292 ft. was ledge, our estimate was $3,005. We paid the contractor $4.00 per foot for the ledge and 75c per foot for 552 ft. of dirt and installed the pipe with our own men at a total cost of $3,159. The total cost per foot over-all by contractor was $3.73 as compared with $3.56 which we had estimated.

A better comparison can be shown of the saving which can be made with a trenching machine on a short job of approximately 295 ft. of 2 in. pipe in dirt. We estimated $487 for hand work under present wage rates, but actually did the job with our own Barber-Greene Trencher for $290 or 98c per foot.

As a contrast, we completed 234 ft. of 2 in. extension with our own crew and without trenching machine at a cost of $360, or $1.53 per foot, and in another instance we laid 149 ft. of 2 in. at a cost of $315, or $2.11 per foot.



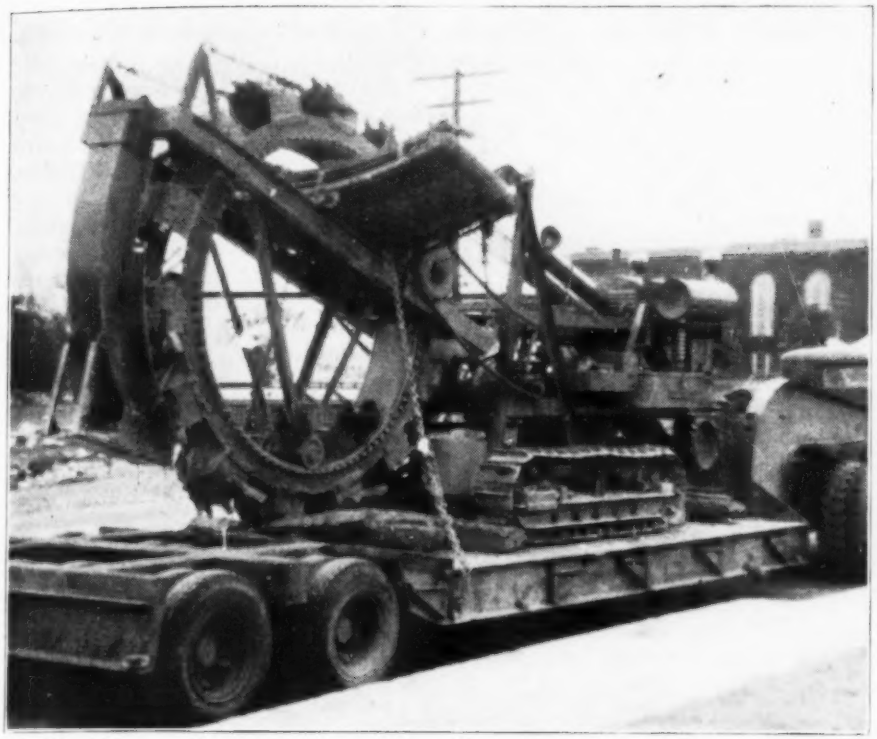
Truck Loader Made by Southworth Machine Co. of Portland, Me.

This machine, which can be attached to any truck of proper size, is used only for loading. It carries a quarter yard bucket, but larger buckets can be had. It costs approximately $700 installed. On left the bucket is in position for backing into pile of dirt or other material. As the truck pulls away the bucket rises and dumps. Note treads under wheels to make bucket raising positive by precluding wheel spin.

Contributions in aid of construction of main extensions were numerous during 1946—mostly for the reason that the demand for water service was so extensive that we sometimes had half a dozen different construction jobs going at the same time.

Our estimate in a dirt trench for 293 ft. of 6 in. main was $778. By contract at 50c per foot for trench and backfill we did it for $693.

Also, 292 ft. of 6 in. main in solid ledge was estimated to cost $1,700, but was completed by the contractor, who was paid $4.00 per foot for ledge and backfill, with our crew installing the pipe, for $1,325, or a total cost of $4.50 per foot.



The Buckeye Trencher

Especially good in soft digging, this wheel type trencher does a low-cost and efficient job.

Some applicants for water service worked on the trenches in order to hurry up the installation and were glad to contribute their labor to get water more quickly. In fact, some had already dug the trench before the application for water was made at the office. Most of these contributions were in locations where service might have been impossible, because of excess cost, unless the trench had been furnished.

Machine Methods a "Must" Under Today's Conditions

From our experience it is evident that future water works extensions must be completed with machinery in contrast to hand work. Furthermore, it is probable that a reputable contractor can do the trenching better and cheaper than our own organizations. Care must be taken when the contract is made with the contractor, that he should be adequately insured against accident and liability, workmen's compensation and any other risk on street work. Under the terms of the present Maine law it is necessary that the trench be paid for and replaced as "good as it was originally"—and it must be kept safe from claims for accidents, for just how long the utility has no means of knowing.

Let us now leave the construction end of the work and see how the engineering, accounting and office end of this work is handled. It is just as important to keep a good office record as it is to do a good job in the field—in fact, the costs which are shown in the office make up the valuation of the plant.

When a request is received for an extension, the first duty of the utility is to have the engineer make a detailed survey of the proposed extension showing the length, size of pipe, ledge conditions, fittings required, street openings, also consumers and hydrants—the total estimated cost and also the estimated income to be received from same. A plan is also required for the construction department.

Extension Cost Records

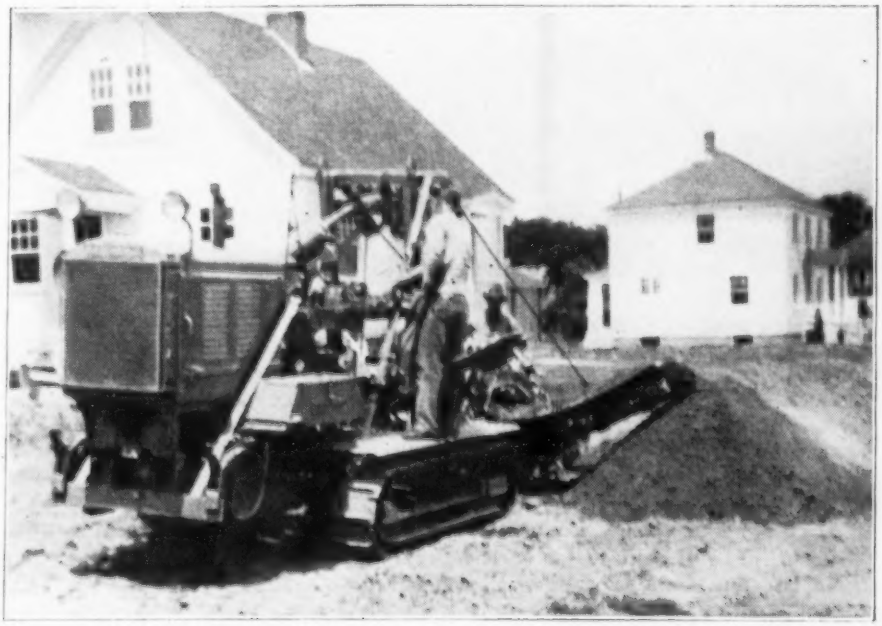
If the extension is approved by the Board, a written order is made on a job card and an extension card. To these is attached the engineer's plan of the job. Service applications consisting of a job card and a service card are sent to shop for installation. These cards are returned to the office when job is completed and these constitute the permanent records of the cost of installation of mains and services.

Much can be said of different forms for use in accounting for fixed capital expenditures.

These record and cost cards present to the engineer and the auditor the faithful reproduction of the costs to the utility. The cost of labor is carefully separated and separately totalled, also the cost of the material used. In addition, the overheads are shown as 20% on labor and 10% on material. The grand total of the job can then be compared with the estimate above on the card.

The Matter of Overheads

Naturally some questions may be raised as to the percentage of overheads. Why 20% on labor and why 10% on material? The only answer to this is that the only method to arrive at a correct figure in the cost of the extension is that the overheads must be properly apportioned. Probably our overheads may be too



The Wheel Type Trencher at Work

In this picture the wheel is hardly visible because it is down in the trench.

small, particularly on the labor side where costs have advanced beyond 20%. However, this can be left to the judgment of the officials. Ten per cent on material is probably sufficient to cover loading, storage, handling, etc.

The overhead costs are changed materially when work is done for the customer on his premises, as we have found that we cannot afford to do jobbing for the water taker at less than a straight 20% overhead on everything. This is reflected on our books as a slight profit on jobbing, or else, if a deficit is shown, we have not charged a sufficient percentage to make up for the overhead expense.

Method of Allocation

The 20% overhead on new services and renewals of services must be journalized as follows:

All overheads charged on service work in the street which is capitalized is credited to an equalization account. This total equalization is proportioned at the end of the year to reduce operating expenses. The accounts reduced are:

741—Distribution Labor
744—Distribution Supplies and Expenses
800—General Repairs
820—Salaries and Expenses General Officers
821—Salaries and Expenses General Office Employees
822—General Office Supplies and Expenses
822—Telephones
822—Lights
825—Miscellaneous General Expenses
826—Law Expenses
827—Insurance General
827—Injuries and Damages
829—Stores Expense
832—Sickness and Allowance
832—Employees' Welfare — Expense Annuities

On the service work on consumers' property, the overheads are credited to the jobbing account. If the books show a small profit on jobbing, we believe the percentage charged is sufficient as we do not intend to purposely create a profit. All work is intended to be done at cost as far as possible.

We record all of our completed work on extensions also, new services, renewals of services, repairs, leaks, etc., on a 4"x6" card. Different colors are used: white for new service; buff for renewal; blue for repairs and salmon color for extensions. These cards of standard size can be easily filed in steel cabinets in consecutive order, and furnish a reliable record for all the life of the service or extension. Hydrant records are filed in the same way except that a street index is used.

This is not the final touch to the extension record. This comes when the engineer draws the red lines on the large maps where all existing mains are indicated, also ledge ditches as well. When the map is consulted we then feel confident to advise prospective water takers just where the mains are and the size.

Something New in Valve Testing

During the past winter, the Indianapolis Water Co. tried something new in its routine testing of valves up to 8 inches. In the past these valves had been tested with hand keys, a slow and laborious procedure. Now, according to a recent issue of the Indianapolis Water Company's "Water Lines," the method is to use an electric nut-runner, powered by a portable electric generator on a truck. This new piece of equipment eliminates approximately 75 per cent of the work formerly involved. The valve stem is run up and down, and the rounds counted by counting the revolutions of a yellow dot on the nut-runner key. Reports are made of the number of rounds and the needed repairs as indicated.

In these valve testing routines, the survey includes not only the stem but the stuffing box, gates, hood, gear, keynut, and the valve box, or pit. Corrosion of the stem and gates is taken care of at the time of testing by running up and down. On larger valves, an air compressor is used for this testing job.

The Indianapolis system contains 7,488 valves, including main line, hydrant branch, blowoff, and flusher valves.

Harvey Ludwig and Vinton Bacon Join in Establishing Consulting Firm

Offices Located in Pasadena, Calif.

On May 1st, two young engineers, Harvey F. Ludwig and Vinton W. Bacon formed a partnership as Consulting Sanitary Engineers and established offices at 608 South Fair Oaks Ave., Pasadena, Calif.

Mr. Ludwig is a Univ. of California graduate (B.S. 1938, M.S. 1942) and served with the U. S. Public Health Service during the war and later with UNRRA on operations in the Middle East and in Jugoslavia. Prior to his war service he was engaged in engineering projects at Berkeley, Calif., and since July, 1946, he and Mr. Bacon have conducted the field operations in the Sewerage Survey for Orange County, California.

Mr. Bacon is also a Univ. of California graduate (B.S. in Civil Eng., 1940) and has since worked with various sewerage organizations, including the East Bay Sewage Disposal Survey, the Los Angeles County Sanitation District and the Orange County Sewerage Survey. He too served with the U. S. Public Health Service during the war.

STORAGE ON THE DISTRIBUTION SYSTEM*

By CHARLES B. BURDICK
Cons. Engr.
ALVORD, BURDICK & HOWSON,
CHICAGO, ILL.

IT HAS been aptly said that elevated storage is like money in the bank. It represents work already accomplished and an asset that can be drawn upon for instant use when needed.

Unlike storage on any other part of the water works system, storage on the distribution system is actually beneficial to every part of the water works, extending all the way back to the source of supply, through feeder pipes, pumps, treatment facilities and, in many cases, the water development facilities.

Like money in the bank, wherein only a certain amount is necessary for day to day commercial transactions, enough is enough. Money invested in excessive storage would better be devoted to something more needed. It is the present purpose to show how much storage may be warranted under general conditions and the available means for accomplishing it, bearing in mind that no two cases are exactly alike and that while the conditions surrounding most water works are similar, there are wide variations in conditions affecting certain cases. Therefore each case should have separate study if the project is to be both technically and economically sound.

The Author
Honorary Member, AWWA and ASCE

Generally speaking, that water works system is the best that provides facilities adequate to meet all conditions of service, including rare emergencies, at the least cost. The latter takes into consideration expenses of operation balanced against capital costs, usually represented by interest and depreciation upon the investment.

Storage upon the distribution system is of principal value in the form of adequacy and reliability of service, and in its economy. It is justified to the extent that it increases more constancy of pressures and greater reliability and economy, bearing in mind that in practically all installations allowance must be made for the probable service requirements for a reasonable period in the future. Both reliability and economy are promoted by the effects of storage in securing more economical pumpage, and in providing an assured pressure and

*A basic discussion of this important topic prepared especially for the Reference and Data Number of *Water & Sewage Works* at our request.—The Editors.

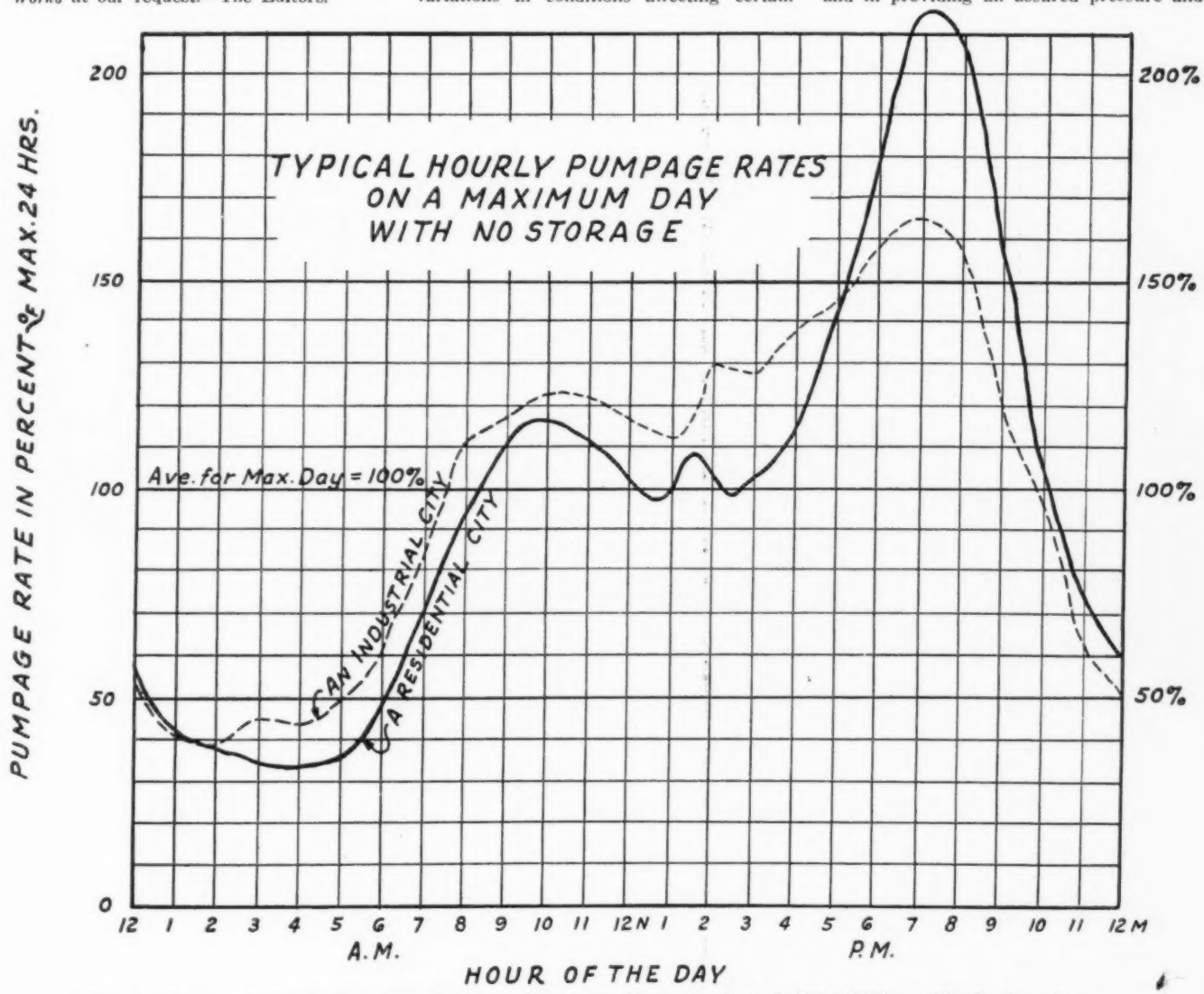


Fig. 1.—Range of Hourly Pumpage Rates on Maximum Days—Typical of Cities Without Distribution Storage. (Pattern for residential city compared with industrial city.)

adequate volume of water for fire protection.

Conditions Affecting Storage

Every water works man would have his problem much simplified, and the investment in water works would be much reduced, if water could be served at a uniform rate of delivery throughout the year. This is impossible, however. The consumer properly demands water when he needs it, and needs vary widely with the seasonal extremes and wide variations in demand throughout the hours of the day.

Storage is particularly beneficial in the afternoon or evening hours upon a few days in exceptionally hot and dry summers. Such summers do not come every year, and therefore excessive demand often comes as a surprise. An examination of many pumping records indicates that the demands of one summer in five or ten may greatly exceed the ordinary summer. Therefore, in providing facilities for storage it is wise to allow a liberal percentage above average requirements in providing storage facilities.

The accompanying Table I is an analysis of the service requirements on five water works systems in cities varying from 37,000 to 320,000 population during years that are known to represent a well defined maximum in each city.

In these statistics the hourly pumpage rates were studied and correction was made for a small amount of elevated storage in several cases so that the figures would represent pumpage necessary to supply demand without storage. Fig. 1 shows diagrammatically the hourly rates of pumpage upon a maximum day for two cities, which represent common maximum and minimum conditions as to pumpage variation. There are some very large cities where use is more uniform. For more ready comparison, the pumpage rates have been expressed in percentage of the average pumpage rate (total pumpage) during the 24 hours of a maximum day. With information similar to this for any city, it is possible to compute the amount of storage which if most effectively liberated would make it possible to operate the pumps at a uniform rate throughout the 24 hours of a maximum day. In other instances, notably the small municipality, adequate storage can sometimes make possible the complete pumping requirement during the period of money-saving off-peak power rates.

TABLE 1
Variations in Pumpage in Five Cities

Character of City	1 Residential	2 Industrial	3 Residential	4 Residential	5 Industrial
Population	37,366	100,426	110,468	307,000	320,000
Ave. pumpage MGD	3.69	9.61	6.94	17.50	43.80
Gals. per capita	99	96	63	57	137
Max. 24 hrs. MGD	5.09	17.42	13.66	30.65	70.20
Gals. per capita	136	174	124	100	220
Per cent of ave. day	138%	182%	196%	175%	160%
Max. hr. MGD	8.05	35.80	30.36	53.00	115.70
Gals. per capita	216	358	278	174	360
Per cent of max. 24 hrs.	158%	205%	222%	172%	165%
Storage to Equalize Hour Peaks					
In gals. per capita	24	33	31	14	50
In % of max. 24 hrs.	18%	19%	25%	14%	23%
Reduced Pumpage Peak by Storage In—					
Gals. per capita	80	184	154	73	140
Per cent of max. 24 hrs.	37%	51%	55%	42%	39%

Hourly variations in pumpage depend upon the character of the city in regard to similarity of use. Perhaps the most important consideration is the extent of industrial use. This can be and usually is a more or less uniform use. Upon the other hand, residential consumers use little or no water at night and make heavy demands at certain hours of the day, particularly during the early evening hours; and to this is added a very exceptional demand for lawn sprinkling on hot summer days. Recently, water used in cooling systems has placed an added burden on hot weather peak hours. In most cities the varying residential demand is more or less ironed out by commercial and industrial uses, and the extent of commercial and industrial use is probably largely accountable for

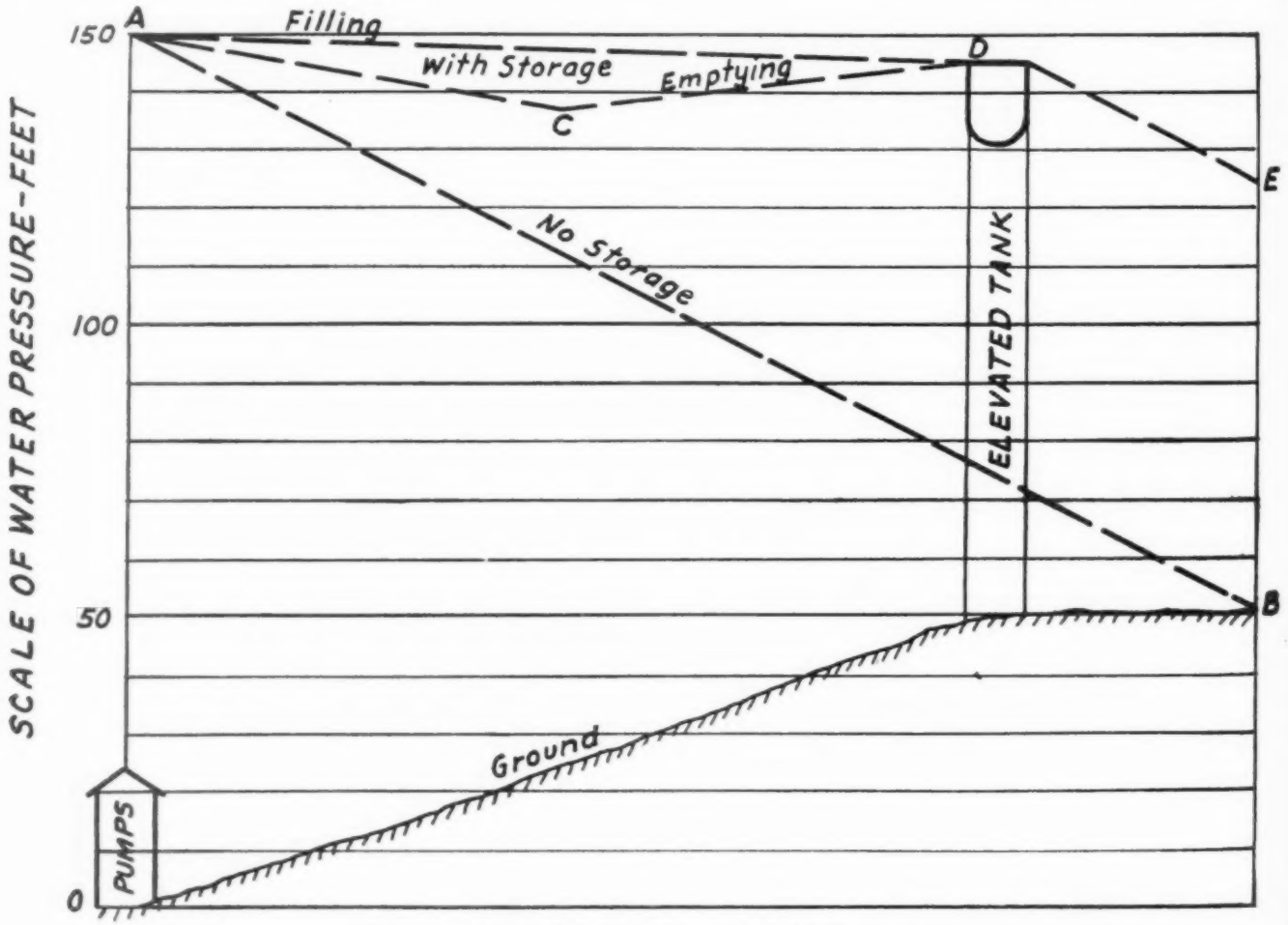


Fig. 2.—Effects of Distribution Storage Available Pressures
(Shown for a maximum demand day.)

differences in pumpage rates when comparing cities.

How Storage Improves Pressure

Fig. 2 is a cross section showing ground occupied by a city, and certain lines illustrating available water pressure created by a pumping station.

The line AB illustrates the drop in pressure in a case where no elevated storage exists, and pump pressure is so used up in deficient pipes that no pressure remains at the peak hour of the heaviest pumpage (demand) day at the remote end of the town.

With an elevated tank installed the pressure conditions are changed as follows upon a similar heavy pumpage day. Assume the storage is such that the pumps instead of running at a variable rate run a constant rate day and night. During the peak hour of use pressure will be represented by the line AC representing water flowing from the pumps. The line DC represents water flowing from the tank toward the pumping station, and line DE, flowing from the tank away from the pumping station. The pressure losses at points between tank and pumping station are smaller than before because this district is being fed from two ends. This results in shorter travel, smaller velocities and greatly reduced friction losses. At points beyond the tank friction losses are the same as before but pressure is increased because the water is coming from the tank at a high elevation.

The conditions noted prevail approximately during the peak hours when use exceeds pumpage. After the peak is past and pumpage exceeds use, during night hours, the pressure approaches the line AD which represents conditions just as the tank is filled. The lines AC, DC and DE will be lower as the tank is depleted; and when an empty tank begins to fill the line AD will be much steeper.

The above illustrates the general result when storage is added without increasing the distribution feeders. Storage is an alternative to new and larger pipes and pumps.

Location and Height

A number of local conditions enter into the question of the best location for storage and the most suitable elevation. Storage is almost always an addition to an existing plant and therefore it must fit existing facilities as well as possible. The following general principles should be guides:

1—Storage should be reasonably close to heavy peak drafts of water and on the opposite side of such points from the pumping station.

2—Elevated storage at the pumps helps the pumps but does not add to the capacity of the distribution system, which involves more than half the cost of the average water works.

3—Elevated storage on the opposite side of heavy draft permits water to be fed from both ends of the distribution system, thus nearly or quite doubling the capacity of the feeders.

4—The top of the stored water will necessarily be slightly below the maximum existing pressure plane of the pumps; but must *not* be too high to fill in the night hours of a peak day. The depth should be as shallow as reasonably possible; 20 to 25 feet is common.

5—The value of storage is largely lost when too far away. Costly pipes can overbalance the advantage of storage.

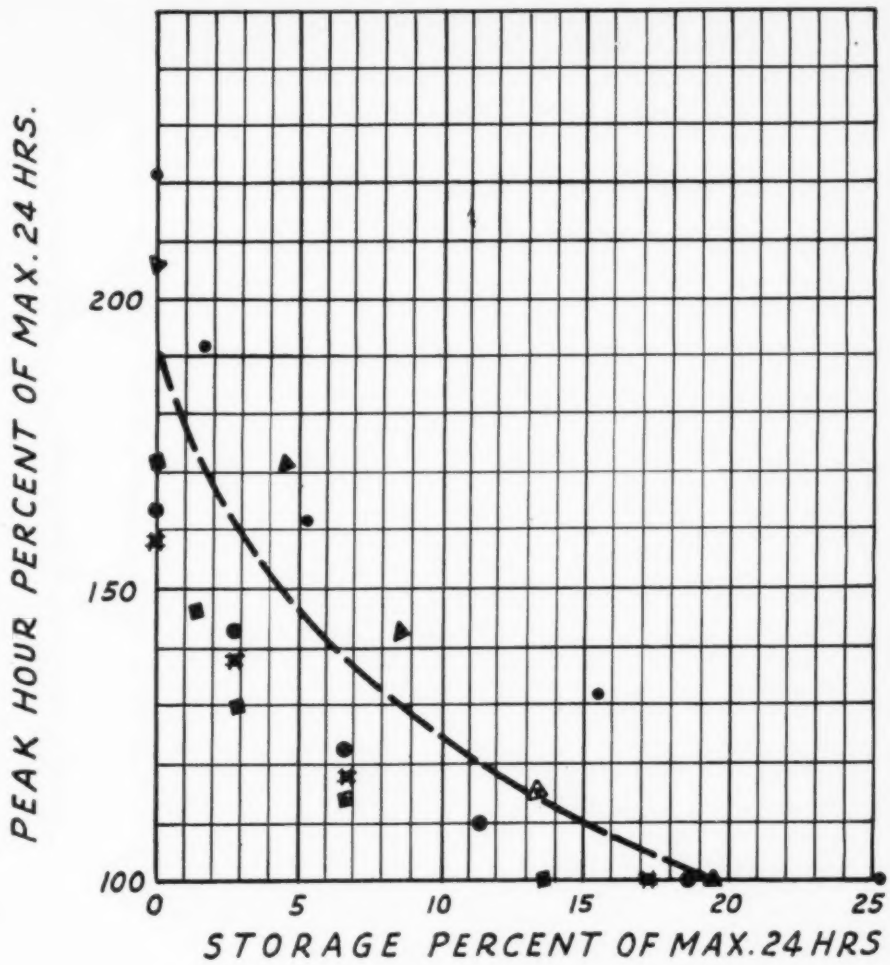


Fig. 3.—Effects of Storage on Pumpage Peaks in Five Cities
(Expressed in per cent of max. 24 hr. pumpage on maximum demand days. Each symbol of different design represents one of the five cities covered in Table I.)

Amount of Storage Required

Fig. 3 shows the amount of storage necessary upon a maximum day to reduce the pumpage to a constant rate throughout the 24 hours of such a day. It also shows the effect of various lesser amounts of storage in reducing the peak hour requirement. The curve shown on the diagram is a median line between the extremes represented by dots upon the diagram. Each dot represents a computation for one of the five cities shown in Table I. It will be observed that a large benefit in pumpage reduction can be secured from a relatively small installation in storage.

These data indicate upon the average that 20 per cent of the maximum day in elevated storage may be expected to reduce the maximum hourly peak about 45 per cent. Or, expressed in another way, in the five cities studied 30 gallons per capita in storage might be expected to reduce the maximum hourly pumpage peak rate 126 gallons per capita if the storage is most effectively used.

In determining how much elevated storage shall be built, consideration is properly given to the existing installations in water supply facilities. The system as a whole must be designed for the maximum requirements for water, which must include the maximum requirements for fire protection if good fire protection service is furnished. In each case a proper installation is a coordination between elevated storage, water supply, pumps and distribution pipe facilities, so adjusting these facilities means that adequate service is furnished at least cost.

Fire Protection

One of the most important benefits from elevated storage is the ability to respond instantly to the heavy draft of water required for fire protection. In the smaller towns this furnishes an especially valuable service while pumps are being started, for many such systems pump intermittently.

In Table 2, column 4, there is shown the rates at which water should be furnished to comply with recommendations of the National Board of Fire Underwriters for cities of various sizes. For comparison there is also shown the average and maximum rates of pumpage based upon the average of the five cities shown in Table 1.

For the smallest town the fire demand is nearly five times the peak hour use, and pumps and distribution system must be designed accordingly without storage, bearing in mind that about 50 per cent above the average domestic demand plus the fire demand must be accommodated.

In towns over 25,000 the peak hour and the fire demand are about equal. In cities of 100,000 or more the combined domestic and fire demand is less than the domestic peak hour demand, and fire protection ceases to be a controlling factor so far as rates of pumpage are concerned.

It should be borne in mind that adequate fire protection provides for very rare emergencies. Likewise, the maximum storage

TABLE 2
Rates of Pumpage Required in Cities of Various Sizes

Population	1 Ave. MGD. at 100 Gals. per Capita 100%	2 Probable Peak 24 Hrs. MGD. 167%	3 Probable Peak Hr. MGD. 308%	4 Max. Rate for Fire Protection MGD.	5 Storage for Hourly Peaks 20% of Max. Day
1,000	.1	.17	.31	1.44	.033
2,000	.2	.33	.61	2.15	.066
4,000	.4	.67	1.24	2.86	.134
10,000	1.0	1.67	3.08	4.30	.334
28,000	2.8	4.66	8.64	7.15	.932
60,000	6.0	10.00	18.50	10.00	2.00
100,000	10.0	16.70	30.80	12.90	3.34
200,000	20.0	33.40	61.60	17.20	6.68

for domestic peak hours is needed on only a few days in exceptional years, and usually an installation contains a reserve for future growth. Therefore an installation proportioned for domestic service is an important addition to the fire protection. It alone provides ample water for the great majority of fires, and the first and more important water in exceptional fires. Its great value is its readiness to serve.

Types of Distribution Storage

Various types of distribution storage are best adapted to special conditions. These types are summarized as follows:

1—Most of the cities in this country are relatively flat and the elevated tank of steel is most widely used. It is now built in shallow depths so that all the water is stored at sufficient elevation to be useful. Sizes as large as 2 mg. are available. Recent designs present a very pleasing appearance.

2—There are some situations where elevated ground is available but not high enough for a concrete reservoir on the ground. In such situations circular steel tanks up to 40 to 60 ft. high and of large capacity can be built for less than half the cost of elevated tanks per unit of capacity. Such tanks can sometimes be scattered at more than one location with beneficial results. For the higher of such tanks all the water may not be fully useful but it furnishes a cheap support for the more useful elevated water.

3—Many cities are so fortunate as to have elevated ground sufficiently high to accommodate elevated reservoirs. These cost about half as much as most elevated tanks. Most recent reservoirs are covered, built of reinforced concrete buried in the ground, and have long life with small maintenance costs. Reasonable cost favors large capacities. In some installations the entire fire protection water is stored in addition to domestic requirements. As much as 100 to 300 gallons per capita is stored in some cities.

4—Where elevated ground is not available it is sometimes economical to build concrete reservoirs or steel tanks on the ground, fill them at night with water bled from the mains and repump stored water back into the mains by remote controlled or automatically controlled electric pumps. The capitalized cost of repumping should, of course, be charged to the installation. In cost comparisons such pumping may be less costly than might be thought if operation is required only a few hours per day during a limited portion of the year.

Operation of Storage

Money should be conserved for use. Likewise water stored should be conserved so that it will be available when needed. There is little use for storage during about 80 per cent of the normal year. With storage it becomes possible to run pumps at a nearly uniform rate, with attendant advantages of economy, and on normal days to utilize only a few feet of the upper part of the storage. The storage should only be materially exhausted during the peak hours of the heavy pumpage days, and always refilled before morning.

Water works men are now more firm than ever in the belief that storage on the distribution system pays its way in the reliability and economy of water service.

Paul Weir Becomes Gen'l Mgr. Atlanta Water Works

Paul Weir, former Supt. of Filtration and recently Ass't Gen'l Mgr. of the Atlanta Water Department, was appointed General Manager July 1, 1947, by Mayor William B. Hartsfield. Mr. Weir has been with the Atlanta Water Department nineteen years.

Mr. Weir received his professional training at the Georgia School of Technology, majoring in sanitary and hydraulic engineering. He has been a member of the American Water Works Assn. eighteen years, was chairman of the Southeastern Section in 1940, chairman of the Water Purification Division of A.W.W.A. in 1941 and national director from 1943 to 1946.

He was the recipient of the Fuller Award in 1940 for his engineering leadership in the Southeastern States and was voted the Goodell Prize of the American Water Works Assn. in 1941 for his scientific research and experiments in "Corrosion Control and Protective Pipe Linings."

Mr. Weir was one of the founders and the mainspring of the Georgia Water and Sewage School at Georgia Tech and has served as its president and secretary. He is an Associate Member of the American Society of Civil Engineers and former president of the Georgia Section. He is a member of the Georgia Public Health Assn., Georgia Mineral Society and the National Society for Professional Engineers. He is the author of a number of technical papers on water supply engineering and administrative subjects, several of which have been published in this magazine. He is currently president of the Georgia Engineering Society, which represents thirty-nine national engineering chapters and has nine hundred members.

Mr. Weir is a Scottish Rite Mason, a Shriner and a Past Master.

He is a member of the Atlanta Kiwanis Club and currently a member of its board of directors.

He is a commissioner of the Boy Scouts of America and a member of its National Council.

Most of all, Paul Weir is a capable water works man with an ability which has won for him this career appointment, so well deserved.

In a private communication he expresses but one regret and that is that this promotion is to cost him the anticipated pleasure of attending the 1947 Convention of A.W.W.A. in San Francisco, which will be the first A.W.W.A. convention that he has missed in 18 years.

Opening for Sanitary Chemist at Georgia Tech

According to George W. Reid, Associate Professor of Sanitary Engineering, the Georgia School of Technology in Atlanta, Ga., has an opening for a young sanitary chemist or engineer to work with Professor Reid and Dr. Ingols on research on the application of rapid physical and chemical methods of water and sewage analysis.

This research work can be applied towards an advance degree.

For information write George W. Reid, Associate Professor, Sanitary Engineering, Georgia School of Technology, Atlanta, Ga.

R. S. Phillips Now at Charlotte, N. C.

Robert S. Phillips, who was formerly chief chemist of the Durham, N. C., water and sewer department until his entry into military service, returned from the war this year to become sanitary engineer and superintendent of plant for the Charlotte, N. C., water department.

Until he entered the army Mr. Phillips was secretary-treasurer of the North Carolina Section of AWWA. During his service in the Sanitary Corps in '45 and '46 he was department sanitary engineer for the Panama Canal Department in charge of malaria control activities in the Canal Zone area. Prior to that he spent a year as medical inspector in two Florida hospitals.

THE A-B-C OF DEPRECIATION*

By JOHN H. MURDOCH, JR.
Chief Counsel
AMERICAN WATER WORKS & ELECTRIC CO.
NEW YORK CITY

THE definition of depreciation often used today is this:

"Depreciation," as applied to a depreciable utility plant, means the loss in service value not restored by current maintenance, incurred in connection with the consumption or prospective retirement of a utility plant in the course of service, from causes which are known to be in current operation and against which the utility is not protected by insurance.

In the 1944 Report of the Committee on Depreciation of the National Association of Railroad and Utilities Commissioners, on page 10 of the Committee print, "depreciation" is defined as follows:

"(a) Depreciation is the expiration or consumption, in whole or in part, of the service life, capacity or utility of property resulting from the action of one or more of the forces operating to bring about the retirement of such property from service;

(b) The forces so operating include wear and tear, decay, action of the elements, inadequacy, obsolescence and public requirements;

(c) Depreciation results in a cost of service."

Unless one wishes to quibble over words, the two definitions convey essentially the same general idea. Here, we want to develop that general idea.

The Nature of Depreciation

When a company purchases a fire insurance policy having a term of five years, it makes an investment in future protection. Money paid for insurance is an operating expense and the money paid for this particular insurance is expense prepaid for five years. The cost of the policy is carried in the balance sheet of the company as an asset in an account which may be called Prepaid Insurance. This item is a prepayment of operating expense and is gradually reduced as the term of the policy expires. As time passes, operating expense accounts for the current periods reflect, each, a portion of this total expenditure and the item of prepaid insurance on the asset side of the balance sheet is correspondingly reduced until at the end of five years it is entirely wiped out. The asset representing the money cost of the prepaid insurance is reduced as current operating expenses have reduced the asset.

In the same way the money cost of chemicals which are bought in bulk and stored for future use is carried on the asset side of the balance sheet as part of Operating Materials and Supplies, and this amount is reduced as the chemicals are used in operations and the cost of the chemicals used in each accounting period appears as an operating expense in the current operating accounts. The original cost of the bulk purchase recorded in Operating Materials and Supplies as an asset is essentially prepaid expense and is written down as the chemicals are used in operations.

*This paper, originally presented by the author in 1940 before the Pennsylvania Water Works Assn., has been revised by request of the Editors and brought up to date for publication in *Water & Sewage Works*.

The Author

President, Pennsylvania Water Works Assn.

In the same way the cost of a boiler is recorded on the asset side of the balance sheet, and, since from its nature and because of the regulations of insurance carriers and state inspectors, we know that the boiler will have a service capacity which will be exhausted at the end of a fixed number of years, we recognize that the cost of the boiler is essentially an item of prepaid expense to be reduced over the years by amounts included in operating expenses. When we think of the matter we see that the costs of buildings, machinery and of all assets which are consumed, worn out or displaced because of service, are all items of prepaid expense recorded on the asset side of the balance sheet, and that because they are prepaid expense items, the items should be reduced by charges to operating expenses equitably distributed over the periods during which each item of prepaid expense serves.

The money which was paid for the acquisition of the asset was not paid for the items of property, but for the capacity to render service or service capacity. In utility practice, "the service capacity" of a plant item means, at any time, the remaining economic usefulness of the plant item for the utility as used and useful property. Wear and tear, obsolescence, governmental orders, exhaustion, consumption—anything which reduces the remaining possible efficient service contents or ability of the item to render efficient service—have reduced the remaining service capacity of the item of property affected. The cost of such service capacity, being prepaid expense, must be apportioned to the periods benefited, through the inclusion in the operating expenses of the periods, of the portion of the original total cost fairly assignable to each such period. As the original cost of this service capacity is written off through operating expenses, the asset is, directly or indirectly, reduced on the balance sheet.

The loss of service capacity is depreciation. The portion of the loss of service capacity which develops during the accounting period is current depreciation and the extent of accumulated depreciation in existing prepaid expense assets is accrued depreciation. In accounting for current depreciation and accrued depreciation, it might be proper to reduce the asset on the balance sheet directly as it is written off through operating expenses. In utility accounting for fixed capital, however, it is not customary to reduce the asset account directly until the property is actually retired from service, but to increase a reserve account sometimes called "Accrued Depreciation Reserve" by periodic amounts corresponding with the portion of the original cost charged to operations during the period. These periodic amounts are recorded in an operating expense account sometimes called "Depreciation Expense." The periodic amounts are intended to write off the original cost of the item of prepaid expense representing service capacity by the time that the service capacity is exhausted. In all of this discussion salvage value and cost of removal are ignored in the interest of simplicity of statement. When the property item is retired its original cost is deducted from both the Fixed Capital account in which it had been entered and also from the Accrued Depreciation Reserve account. The result is that the balance at any time in the Accrued Depreciation Reserve account is equal to the amount of Prepaid Expense in Fixed Capital which has been amortized through Operating Expenses, but for which the corresponding fixed capital property item has not yet been retired from service. The portion of Prepaid Expense recorded in the Fixed Capital asset accounts which has not yet been amortized through Operating Expenses, is equal to the difference between the balance in the Fixed Capital asset account and the balance in the Accrued Depreciation Reserve account.

Analyze the Definition

Now let me repeat the definition:

"Depreciation," as applied to a depreciable utility plant, means the loss in service value not restored by current maintenance, incurred in connection with the consumption or prospective retirement of a utility plant in the course of service from causes which are known to be in current operation and against which the utility is not protected by insurance.

Examine some of those words and phrases.

It seems to be generally agreed now that the words "service value" in the definition are the equivalent of the words "service capacity," and we have seen that "service capacity," at any time in the life of a plant item, means that plant item's remaining economic usefulness for the utility. That is one aspect of service value. The words also have in them the idea of value as service units to the utility as distinguished from value in exchange, second hand or as scrap. Some witnesses in the past have seriously testified to accrued depreciation as being the difference between cost new and scrap or secondhand market value. That claim is no longer put forward and "service value" expresses the idea that it has been discarded.

The next phrase is this—"not restored by current maintenance." That phrase is a newcomer in the definition of depreciation. Indeed, many modern definitions, including the 1944 NARUC Committee Report definition, do not contain those words, and they cause great trouble to already troubled minds. Go back into the history of our

subject and we find some interesting facts which may throw some light on why this phrase is often used.

Some students, lawyers and engineers have for years made the claim that depreciation and maintenance are so closely related that there is no loss in service capacity in a well maintained plant item and that the only accrued depreciation possible in a plant is such loss in value or capacity as may be due to deferred maintenance. Those arguing against this thought have in some of their arguments gone beyond what they can prove, but most people now agree that, from one cause or another, many plant elements do suffer a loss in service capacity over the years which cannot be entirely prevented or repaired by current maintenance. All agree that the better a plant is maintained the longer will be the life of most plant items. All agree that each company should follow a consistent policy as to retirement units so as not to inflate maintenance expense by charging to maintenance the replacement of items for which a depreciation reserve has been accrued.

All must certainly agree that a dull knife does not have as great service value or service capacity as a sharp knife, so the dull knife must have suffered depreciation. At each point of time whatever loss of service capacity exists is depreciation, no matter what may possibly be done in succeeding time intervals to restore that loss or to change it. A loss of service capacity is depreciation; a loss of service capacity "restored" by whatever means is not an existing loss. A loss of service capacity which has been restored by current maintenance is not depreciation because there is no existing loss. It is plain that the phrase "depreciation is a loss of service value not restored by current maintenance" is merely a rather inartistic attempt to incorporate in the definition the idea that some depreciation does develop in spite of current maintenance. Read with that thought in mind, we may paraphrase by saying that "Depreciation is loss in service capacity from any cause known to be in current oneration, which loss may be reduced but not wholly prevented by good current maintenance."

Another part of the definition needs examination. Depreciation is the loss in service capacity ". . . from causes known to be in current operation . . ."

I believe that the idea expressed in those words was incorporated in the standard definition of "depreciation" after Mr. Justice Brandeis, a great lawyer and a great accountant, had pointed out the impropriety of recording depreciation reflecting accruals for contingent losses which might in the future be caused by forces conjured up in the mind and not known to be in current operation and to be affecting the property in question. The idea is essential to the definition, as otherwise depreciation, in extent, would be limited merely by the limits of a diseased imagination.

Some utility industries face the possibility of replacement by competitive industries. As an illustration, the street car industry has for all practical purposes been replaced by private autos and public buses. Similarly, manufactured gas companies face competition as an industry from natural gas companies; gas must compete with oil and with electricity. Perhaps when such competition is known to be developing and when its ultimate effect is recognized, the ultimate loss should be provided for through depreciation accounting, but at least until those conditions develop, the better practice would seem to be to compensate for such possible future loss through the risk element in the rate of return considered fair. Water utilities have not reached the point where depreciation reserve should be built up against the possibility of ultimate death of the industry.

With this definition agreed upon and explained, there is still much room for disagreement because "depreciation," as defined by the one set of words, has still more than one meaning or application. Much of the endless argument on the subject of depreciation can be traced to the refusal of the disputants to recognize these varied meanings and the varied techniques which those differing meanings make necessary.

When depreciation is a factor in fixing the present fair value ot a property, the difference in viewpoint of those who look on the balance in the accounting depreciation reserve as the best measure of accrued depreciation and the viewpoint of those who insist that accrued depreciation should be fixed by observation becomes apparent. This difference in viewpoint may be shown by an illustration based on assumed and highly simplified facts. Assume that a restaurant with a long history is to be sold pursuant to a contract which fixes the price to be paid as the valuation based on the reproduction cost of all equipment less depreciation. The old owners have kept careful check and have determined that the average life expectancy of table water glasses is two years and that they have consistently accrued depreciation through operating charges at the rate of fifty per cent per year on the cost of such glasses. Now assume that on the last day of the year and the day of the sale the actual breakage has amounted to only ten per cent, instead of the estimated fifty per cent, and that the remaining glasses are unchipped, up to date, clear and polished, and just the type which the new owner would buy that day. Is the new owner entitled to have those perfect glasses valued with a deduction for depreciation computed in conformity with the assumption that on the day of sale five times as many glasses would have been broken as were actually broken?

The old owners, being conservative business men, always calculated their operating expenses with an inclusion for depreciation based on their usual experience. For their accounting purposes and to assure continued solvency, they conceived of depreciation on the basis of long term expiration of service capacity calculated from experience, but for the purpose of a spot valuation they used depreciation as meaning a physical and economic fact, not an accounting reserve.

Accrued Depreciation Reserve and Depreciation Expense Account

If the periodic charges to operating expenses in the Depreciation Expense account have accurately reflected the extent to which the fixed capital assets have been used up in service during the various periods, then the balance in the Accrued Depreciation Reserve account will be the measure of the loss in service capacity suffered by the assets which are still recorded in Fixed Capital. If there is not this accurate reflection, the Accrued Depreciation Reserve account will reflect, but will reflect merely, the extent to which Prepaid Expense items in Fixed Capital have been written off through operating accounts. In either case the balance in the Accrued Depreciation Reserve will reveal facts, but the facts revealed will be of different natures. In the one case the fact will be the physical and economic fact of actual loss in service capacity expressed in dollars, while in the second case the fact will be the financial one of the extent of the amortization of prepaid expense. A method of calculating the operating expense item of Depreciation Expense may be perfectly sound as a financial method of amortizing prepaid expense recorded in Fixed Capital and unsound as a method for determining the physical and economic fact of actual loss in service capacity as of a certain date.

Assume for a moment that the balance in the Accrued Depreciation Reserve account does actually reflect not only the extent of amortization of prepaid expense, but also the extent of actual loss of service capacity existing in fixed capital assets, then the Accrued Depreciation Reserve account may be aptly likened to the hole in the doughnut. The true remaining asset is the doughnut with the hole as it exists. This Accrued Depreciation Reserve is clearly not an asset, but a hole in an asset, a deduction from an asset. The Reserve when so considered is clearly not a source of funds for replacements. The funds come from retained expenses—not from the reserve.

Adequate charges for depreciation expense have the effect of retaining in the business funds which might otherwise be paid out in dividends. The funds so retained in the business represent capital available for financing property replacements or additions, retirement of debt or other proper corporate purpose. It is usual in utility practice to invest such funds in property and plant as almost all utilities are constantly in need of new funds for fixed capital.

Utility Base Rate

In a Utility Lifetime View the Utility Rate Base Is Not Reduced by the Deduction of Accrued Depreciation

Let us assume that a utility's rates will be based on some dollar figure, "X," less accrued depreciation, and to avoid discussion and qualifications, let us assume at this point, and this point only, that original cost less accrued depreciation based on cost is the rate base. Let us assume that throughout the entire history of the utility, construction and material costs remain uniform. Let us also assume that the balance in the Accrued Depreciation Reserve account will be considered at all times to represent actual loss in service capacity. Also we will assume, what would be the fact, that the funds retained in the business through charges to Depreciation Expense are invested in the plant.

I will state what happens, although my statement may be very much simplified by the omission of compensating side steps. Here again salvage and cost of removal will be disregarded.

The Accrued Depreciation Reserve has added to it each year the amount of the Annual Depreciation Expense and has deducted from it the actual retirements during the year. On the other hand, the Fixed Capital asset account has deducted from it each year the same dollars of actual retirements and has added to it the same dollars in funds retained in the business through Depreciation Expense charges and invested in fixed capital. Both Fixed Capital Assets and Accrued Depreciation Expense will be increased each year by the same net amount if no new capital be added. The net of Fixed Capital assets

less Accrued Depreciation Reserve remains constant and that net is the rate base of the utility under our present assumptions.

Annual Depreciation Expense

The Higher the Annual Depreciation Expense of a Utility the Higher Service Rates Must Be

It is axiomatic that utility rates must be sufficient to cover the entire cost of service and that the entire cost of service includes all operating expenses, taxes and a fair return on a fair rate base. We have seen that the rate base is not reduced by the deduction of accrued depreciation if we take the long range viewpoint. We will now assume that taxes and all operating expenses, except Depreciation Expense, are fixed. It then is evident that the higher the annual depreciation expense, the higher the service rates of the utility must be. A utility with a plant of such a nature that it suffers no loss of service capacity, and consequently has no depreciation expense, obviously can render service more cheaply, other things being equal, than a competing utility which must meet an annual depreciation expense.

Effect of Overestimating Depreciation Expense

In order to discover the effect of overestimating depreciation, we will take a simple example. The plant will be taken as having an original cost of $100,000 and as having a rate base each year equal to $100,000, less the accrued depreciation reserve, and we will assume that its rates are adjusted each year to that basis. This particular plant, we will imagine, is so peculiarly constructed and situated that there are no additions to plant and that all replacements are made at one time when the original plant is retired as a unit. In such a case depreciation expense funds could not be reinvested in the plant until the entire plant was ready to be retired and replaced. In this particular and very peculiar plant, the retirement and replacement takes place at the end of twenty years of life.

When the plant was first built, the regulatory body in charge ordered straight-line depreciation expense applied and ordered that the assumed life should be ten years. The depreciation expense would then be $10,000 per year for ten years and a six per cent return on the diminishing rate base would start at $6,000 per year and go down to $600 in the tenth year, a reduction of $600 each year. The total for annual return and depreciation would average $13,300 per year for ten years.

But the plant remains in service for another ten years, although a depreciation reserve of 100 per cent has been built up in the first ten years of its life. The customers of the next ten years may ride free of return on rate base and of depreciation expense because we have assumed that the rate base was to be cost less the depreciation reserve. If the assumed life had originally been fixed at twenty years, the annual depreciation expense would have been $5,000 per year, and the six per cent return on the base would have varied from $6,000 to $300, with annual drops of $300. In case of a twenty year assumed life, however, the total for the annual return on rate base plus the depreciation expense during the first ten years would average $9,650 against an average of $13,300 when a ten year life was assumed.

It appears then that while the customers in the last ten years ride free of return on rate base and of depreciation expense when a ten year life is assumed, it is because the customers in the first ten years paid far more for their service than their fair share of the total costs.

Like all estimates of the future, the estimating of Depreciation Expense cannot be exact. Errors will be made and will have to be adjusted, but that method of estimating should be employed which is least apt to produce serious errors and which will in theory come closest to actual physical and economic facts. In this I assume that everyone wants to have depreciation reflect, as nearly as possible, such physical and economic facts.

Age-Life Methods of Calculating Depreciation

By examining some elementary facts and principles, I want to find just how firm a foundation is laid for age-life depreciation as the sole method which should be employed under all conditions and for all purposes. For many purposes age-life straight-line depreciation may be satisfactory and sound if based upon a thorough study of plant history and if it fairly reflects that history, but for valuation purposes as of a fixed date it may be unsound and inappropriate as in the restaurant sale case.

By the term "age-life depreciation," I mean any method of calculating accrued or annual depreciation, based on the assumption or calculation of either a total life expectancy or a remaining life expectancy for the physical property of a utility. Included among such methods are straight-line, sinking fund, compound interest, annuity and remaining life depreciation and any and all combinations or modifications of them. All rest on the theory that depreciation is a function of time. By that, I mean that the advocates of age-life depreciation as the universal method believe that for each unit of time in the life of a plant item, there is a corresponding increase in loss of service capacity.

All of the age-life depreciation methods, if correctly applied, applied consistently to both annual and accrued, and applied throughout the entire life history of a utility or with corrections to compensate for past under- or over-accruals will correctly amortize the prepaid expense recorded as a part of Fixed Capital on the asset side of the balance sheet. However, it must be borne in mind that a shifting from one method to another may work injustice and bring unsound results, and in attempting to compensate for these shifts of method, injustice may be done to either past or future customers.

It must not be forgotten that the different methods of age-life depreciation do not all equally approximate the physical and economic facts of actual loss of service capacity.

If the various age-life methods in common use were all equally efficient in approximating at all periods of a life cycle the actual physical and economic facts of loss in service capacity, there would necessarily be but minor spreads in the results of computations by the various methods. This is far from being the case. Apply four different methods to calculate the annual depreciation expense and the accrued depreciation on a unit of ten inch cast iron pipe costing $1,000 and still in service and good standing in its community at the end of twenty-five years from its installation and with an assumed life of fifty years. On straight-line calculation the accrued depreciation is $500 and annual depreciation expense is $20; on two per cent compound interest method accrued is $378.69 and annual expense is $19.39; on four per cent compound interest method accrued is $272.78, annual expense $17.46; on six per cent compound interest method accrued is $188.73, annual expense is $14.76. By varying the method and the assumed interest rate to be earned on accumulations from zero per centum in straight-line depreciation to six per centum, but keeping the same total life assumption, we get a result for accrued where the highest is 2.64 times as large as the lowest, and for annual expense where the highest is 1.35 times the lowest. While all four methods are mathematically sound for a calculation of capital amortization during the assumed life, since they vary widely they cannot be equally sound as a method of finding actual loss of service capacity.

It must not be forgotten that this unit of pipe is still in service and that the assumption of a total life of fifty years was made when the pipe was installed twenty-five years ago. If one estimator chose to assume a total life of fifty years for this pipe and another chose to assume a total life for the same pipe of seventy-five years, and a third chose to assume one hundred years, and each estimator at the end of twenty-five years of service for the pipe calculated the accrued depreciation in this pipe at that time and the annual expense for depreciation for that pipe for that year, and each used the four sample methods—straight-line, two per cent compound interest, four per cent compound interest and six per cent compound interest—the variations in the results would be fantastic. The highest accrued depreciation would be $500 and the lowest would be $9.73; the highest would be 50.6 times the lowest. The highest calculation of annual depreciation expense would be $20 and the lowest would be 76 cents; the highest would be approximatelv 25 times the lowest. All of the methods used would correctly amortize the capital in the assumed number of years of total life, but some or all of the methods or assumptions must be weird if they are to be used to determine actual loss in service capacity.

Many advocates of age-life depreciation argue that straight-line methods result in lower charges to the consumer than where compound interest methods are used. Is this a fact? Assuming the same total service life expectancy, the total charges to the consumer will be identical under either straight-line or compound interest methods. (See Study I, Columns 1 to 9, inclusive.) This is true unless the depreciation allowance is so high as to make it impossible for the utility to find investments in its own plant in used and useful property for its assets retained through depreciation accounting. (See Study I, Columns 10, 11 and 12.)

If the method be changed during a series of service years of a plant from a compound interest method to a straight-line method, then the total payments will be substantially reduced. Compare Studies I and II. This is a demonstration of the fact that it is unfair to a utility to require it to change to the straight-line method from a lower reserve method previously used.

If the assets retained through depreciation accounting be invested in the utility so as to earn the assumed fair return, and if the depreciation reserve be deducted each year in getting the rate base, and if the depreciation allowance and the deducted depreciation be determined consistently one with the other, then the consumers will, during the life of the item, pay the capital

cost of the item plus simple interest on that cost at the fair rate of return. (See Study I, Column 8.) This is true, no matter what interest rate be assumed for compounding under the compound interest method.

Assuming a capital cost of $10,000, a ten year service life and a fair return rate of six per cent, then proper depreciation methods will give the utility from the consumers $16,000 during the period of service. Any method or combination of methods, giving either more or less than $16,000, is unsound. Compare Column 8 in Studies I, II and III.

In Study I, Columns 10, 11 and 12 show the results where the utility cannot find investment for its retained assets in its own plant at the fair rate of return. Under such circumstances, the higher depreciation rates under the straight-line method cut down the rate base on which a fair return can be earned and increase the reserve on which less than a fair return can be earned. Under these circumstances, the straight-line method does result in lower charges to the consumers. (See Study I, Columns 10, 11 and 12.) Thus, by appearing to be generous in the allowance of annual depreciation, a utility commission might require unnecessarily high annual allowances and deprive the utility of a fair return on its property. Note that in Column 11 in Study I, the total of depreciation and earnings is in all cases less than the $16,000 needed to constitute the assumed fair return. Compare with Column 8 in Study I.

Study II shows that a mere change from a compound interest depreciation method to a straight-line method during the life of a property item results in an impairment of capital (Columns 3 and 6), and also results in less than fair total charges being paid by the consumers (Column 8). This shows that while either method followed consistently during an entire period of service life will amortize the capital cost and give a fair return on the property during its use, a change in method during the period cannot be justified unless subsequent charges for depreciation to be paid by consumers be modified.

All of these age-life methods are based on the assumption that the passage of time has some relationship as a cause to the loss in service capacity of plant items. In order to estimate the length of time within which total exhaustion or loss of service capacity will occur, the advocates of age-life depreciation make use of assumed so-called average lives and bolster their statements as to the soundness of their methods by references to the practices of life insurance companies.

The Law of Probabilities

Consider the fundamentals of the law of probabilities. Examine it by example and not by formal statement, and follow it through its applications to life insurance and annuities.

If I toss a coin in the air and bet that it will come up heads, I stand an even chance of winning or losing. I may continue to toss and to bet, and as to each bet, I still have a fifty-fifty chance, but no more than a fifty-fifty chance. If, however, I bet you that out of 1,000,000 throws, heads will come up not less than 470,000 times nor more than 520,000 times, my chances of winning are so infinitely greater than your chances of winning, that you would be a fool and I would be a knave for making that bet. It was not a gamble at all.

STUDY I

Assumptions: One Unit of Property; Actual and Expected Life—10 Years; Cost $10,000; Rate of Return 6% and Actually Earned on Base; for Columns (1) to (9), Inclusive Balance in Depreciation Reserve Actually Earns 6% Per Annum; for Columns (10), (11) and (12) Balance in Depreciation Reserve Actually Earns Only 4%.

	(1) Rate Base Cost Less Prior Reserve	(2) Return on Base 6% on (1)	(3) Annual Depreciation Allowance	(4) Total of Columns (2)+(3)	(5) Present Value of Payments in (4)	(6) Depreciation Reserve End of Year	(7) Earnings at 6% on Reserve	(8) Depreciation + Earnings (2)+(3)+(7)	(9) Earnings (2)+(7)	(10) Earnings at 4% on Reserve	(11) Depreciation + Earnings (2)+(3)+(10)	(12) Earnings (2)+(10)
Straight Line Depreciation Method						See Note B						
1	$10,000.00	$ 600.00	$ 1,000.00	$ 1,600.00	$ 1,509.43	$ 1,000.00	$	$ 1,600.00	$ 600.00	$	$ 1,600.00	$ 600.00
2	9,000.00	540.00	1,000.00	1,540.00	1,370.59	2,000.00	60.00	1,600.00	600.00	40.00	1,580.00	580.00
3	8,000.00	480.00	1,000.00	1,480.00	1,242.64	3,000.00	120.00	1,600.00	600.00	80.00	1,560.00	560.00
4	7,000.00	420.00	1,000.00	1,420.00	1,124.77	4,000.00	180.00	1,600.00	600.00	120.00	1,540.00	540.00
5	6,000.00	360.00	1,000.00	1,360.00	1,016.27	5,000.00	240.00	1,600.00	600.00	160.00	1,520.00	520.00
6	5,000.00	300.00	1,000.00	1,300.00	916.45	6,000.00	300.00	1,600.00	600.00	200.00	1,500.00	500.00
7	4,000.00	240.00	1,000.00	1,240.00	824.67	7,000.00	360.00	1,600.00	600.00	240.00	1,480.00	480.00
8	3,000.00	180.00	1,000.00	1,180.00	740.35	8,000.00	420.00	1,600.00	600.00	280.00	1,460.00	460.00
9	2,000.00	120.00	1,000.00	1,120.00	662.93	9,000.00	480.00	1,600.00	600.00	320.00	1,440.00	440.00
10	1,000.00	60.00	1,000.00	1,060.00	591.90	10,000.00	540.00	1,600.00	600.00	360.00	1,420.00	420.00
		$3,300.00	$10,000.00	$13,300.00	$10,000.00		$2,700.00	$16,000.00	$6,000.00	$1,800.00	$15,100.00	$5,100.00
Compound Interest Depreciation Method—3% Interest Table												
			See Note A			See Note B						
1	$10,000.00	$ 600.00	$ 872.30	$ 1,472.30	$1,388.96	$ 872.30	$	$ 1,472.30	$ 600.00	$	$ 1,472.30	$ 600.00
2	9,127.70	547.66	898.47	1,446.13	1,287.05	1,770.77	52.34	1,498.47	600.00	34.89	1,481.02	582.55
3	8,229.23	493.75	925.43	1,419.18	1,191.57	2,696.20	106.25	1,525.43	600.00	70.83	1,490.01	564.58
4	7,303.80	438.23	953.19	1,391.42	1,102.13	3,649.39	161.77	1,553.19	600.00	107.85	1,499.27	546.08
5	6,350.61	381.04	981.79	1,362.83	1,018.39	4,631.18	218.96	1,581.79	600.00	145.98	1,508.81	527.02
6	5,368.82	322.13	1,011.24	1,333.37	939.97	5,642.42	277.87	1,611.24	600.00	185.25	1,518.62	507.38
7	4,357.58	261.45	1,041.58	1,303.03	866.59	6,684.00	338.55	1,641.58	600.00	225.70	1,528.73	487.15
8	3,316.00	198.96	1,072.83	1,271.79	797.94	7,756.83	401.04	1,672.83	600.00	267.36	1,539.15	466.32
9	2,243.17	134.59	1,105.01	1,239.60	733.72	8,861.84	465.41	1,705.01	600.00	310.27	1,549.87	444.86
10	1,138.16	68.29	1,138.16	1,206.45	673.68	10,000.00	531.71	1,738.16	600.00	354.47	1,560.92	422.76
		$3,446.10	$10,000.00	$13,446.10	$10,000.00		$2553.90	$16,000.00	$6,000.00	$1,702.60	$15,148.70	$5,148.70
Compound Interest Depreciation Method—6% Interest Table												
			See Note A			See Note B						
1	$10,000.00	$ 600.00	$ 758.68	$ 1,358.68	$ 1,281.77	$ 758.68	$	$ 1,358.68	$ 600.00	$	$ 1,358.68	$ 600.00
2	9,241.32	554.48	804.20	1,358.68	1,209.22	1,562.88	45.52	1,404.20	600.00	30.35	1,389.03	584.83
3	8,437.12	506.23	852.45	1,358.68	1,140.77	2,415.33	93.77	1,452.45	600.00	62.52	1,421.20	568.75
4	7,584.67	455.08	903.60	1,358.68	1,076.20	3,318.93	144.92	1,503.60	600.00	96.61	1,455.29	551.69
5	6,681.07	400.86	957.82	1,358.68	1,015.29	4,276.75	199.14	1,557.82	600.00	132.76	1,491.44	533.62
6	5,723.25	343.39	1,015.29	1,358.68	957.82	5,292.04	256.61	1,615.29	600.00	171.07	1,529.75	514.46
7	4,707.96	282.48	1,076.20	1,358.68	903.60	6,368.24	317.52	1,676.20	600.00	211.68	1,570.36	494.16
8	3,631.76	217.91	1,140.77	1,358.68	852.45	7,509.01	382.09	1,740.77	600.00	254.73	1,613.41	472.64
9	2,490.99	149.46	1,209.22	1,358.68	804.20	8,718.23	450.54	1,809.22	600.00	300.36	1,659.04	449.82
10	1,281.77	76.91	1,281.77	1,358.68	758.68	10,000.00	523.09	1,881.77	600.00	348.73	1,707.41	425.64
		$3,586.80	$10,000.00	$13,586.80	$10,000.00		$2,413.20	$16,000.00	$6,000.00	$1,608.81	$15,195.61	$5,195.61

Note A: Annuity plus product of prior year depreciation reserve multiplied by rate of interest assumed in annuity table used.
Note B: Depreciation Reserve as of any year equals sum of all annual allowances for depreciation, up to that time, calculated for each year as explained under NOTE A.

This illustration of what every gambler knows is called to mind because the principle applies to life insurance. The life insurance company can calculate by applying the law of probabilities to actual mortality tables of similar groups what number of persons out of a very large group aged twenty years will die in each succeeding year. The insurance company calculations are based on the assumption that in a homogeneous population, the life experience of a random sample of sufficient size will fairly represent the experience to be expected of any other sample of at least equal size drawn from the same population. Note that the experience is drawn from a large group and is applied to a group of at least equal size. No attempt is made to calculate the life expectancy of an individual or small group of individuals. No reputable doctor, after a physical examination of a normal individual and a study of a mortality table, showing the life experience of a large group of similar individuals, would undertake to predict the life of the individual just examined. All that such a doctor could say would be that the individual examined appeared physically to belong properly in the same group as others of his attained age. A life insurance policy or an annuity issued to one and only one individual or to only a small group would be a mere gambling contract and would be unenforceable as such. It would be just as much of a gamble as a bet on one flip of a coin. On the other hand, when a company issues policies on large groups of individuals and insures each individual as an independent unit and bases its rates for such policies on the law of probabilities, it assumes practically no risk, and the policies are valid enforceable business contracts.

In this same connection, another point must be developed. Life insurance companies in their studies make use of a formula known as the Gompertz-Makeham formula, developed by mathematicians working with the law of probabilities and designed to make possible the working out of mortality curves for human beings where no mortality curves based on actual lives completed are available. In its application several assumptions must be made, one being a definite age assumed for death. Some insurance companies assume this age to be eighty-five, others a higher age. The ultimate limits of human life are so well fixed by the history of millions of lives that the assumed age for certain death will tally very closely with experience. The number of individuals exceeding that ultimate age will be so small as to be meaningless in a calculation of a large group. The formula also assumes that "the average exhaustion of man's power to avoid death to be such that at the end of equal infinitely small intervals of time, he lost equal portions of his remaining power to oppose destruction which he had at the commencement of these intervals." That was the Gompertz part of the formula and to it Makeham added an element to represent death due to chance without previous disposition to death or deterioration. It is found that when the constants in the formula are taken from actual experience tables, the formula produces a curve which follows closely an actual mortality curve. We know from ages of observation that while natural death is a late development in biological history, human death does appear to be certain to come and that the vast majority do die before reaching the age of one hundred years. We also know that all human life does pass through well marked stages, and, therefore, Gompertz's funda-

Note A: Annuity plus product of prior year depreciation reserve multiplied by rate of interest assumed in annuity table used for each year as explained under NOTE A.
Note B: Depreciation Reserve as of any year equals sum of all annual allowances for depreciation, up to that time, calculated

STUDY II

Showing Results of Changing Depreciation Methods During Life of Property. Assume That for First Five Years Depreciation Be Computed on Compound Interest Six Per Cent Method and That Commission Then Makes Computation of Accrued Depreciation and Future Annual Allowance for Depreciation on Straight Line Method.

	(1) Rate Base Cost Less Prior Reserve	(2) Return on Base 6% on (1)	(3) Annual Depreciation Allowance	(4) Total of Columns (2)+(3)	(5) Present Value of Payments in (4)	(6) Depreciation Reserve End of Year	(7) Earnings at 6% on Reserve	(8) Depreciation +Earnings (2)+(3)+(7)	(9) Earnings (2)+(7)	(10) Earnings at 4% on Reserve	(11) Depreciation +Earnings (2)+(3)+(10)	(12) Earnings (2)+(10)
					Compound Interest Depreciation Method—6% Interest Table for 5 Years							
1	$10,000.00	$ 600.00	$ 758.68	$ 1,358.68	$ 1,281.77	$ 758.68	$	$ 1,358.68	$ 600.00	$	$ 1,358.68	$ 600.00
2	9,241.32	554.48	804.20	1,358.68	1,209.22	1,562.88	45.52	1,404.20	600.00	30.35	1,389.03	584.83
3	8,437.12	506.23	852.45	1,358.68	1,140.77	2,415.33	93.77	1,452.45	600.00	62.52	1,421.20	568.75
4	7,584.67	455.08	903.60	1,358.68	1,076.20	3,318.93	144.92	1,503.60	600.00	96.61	1,455.29	551.69
5	6,681.07	400.86	957.82	1,358.68	1,015.29	4,276.75	199.14	1,557.82	600.00	132.76	1,491.44	533.62
					Straight Line Depreciation Method for 5 Years							
1			1,000.00	1,300.00	916.45	5,276.75*	256.61	1,556.61	556.61	171.07	1,471.07	471.07
2	5,000.00	300.00	1,000.00	1,240.00	824.67	6,276.75*	316.61	1,556.61	556.61	211.07	1,451.07	451.07
3	4,000.00	240.00	1,000.00	1,180.00	740.35	7,276.75*	376.61	1,556.61	556.61	251.07	1,431.07	431.07
4	3,000.00	180.00	1,000.00	1,120.00	662.93	8,276.75*	436.61	1,556.61	556.61	291.07	1,411.07	411.07
5	2,000.00	120.00	1,000.00	1,060.00	591.90	9,276.75*	496.61	1,556.61	556.61	331.07	1,391.07	391.07
6	1,000.00	60.00	1,000.00									
		$3,416.65	$ 9,276.75	$12,693.40	$ 9,459.55		$2,366.40	$15,059.80	$5,783.05	$1,577.59	$14,270.99	$4,994.24

*For rate making, Accrued Depreciation is deducted in the amount which would be indicated by the Straight Line Method while the figures used in this column start with the accumulation at the end of the fifth year under the Compound Interest Method and are increased each subsequent year by the Straight Line Method Annual Allowance. These figures, however, represent the accumulation of sums retained, through Depreciation, for investment.

STUDY III

Showing Results of Using Inconsistent Methods for Calculating Accrued Depreciation for Determination of Net Rate Base and Calculating Annual Allowance for Depreciation. Assume Rate Base Be Reduced Each Year by Straight Line Method and That Annual Allowance for Depreciation and Accumulation of Funds Available From Depreciation Retained for Investment Be Calculated on 6% Compound Interest Method.

	(1) Rate Base Cost Less Prior Reserve	(2) Return on Base 6% on (1)	(3) Annual Depreciation Allowance	(4) Total of Columns (2)+(3)	(5) Present Value of Payments in (4)	(6) Depreciation Reserve End of Year	(7) Earnings at 6% on Reserve	(8) Depreciation +Earnings (2)+(3)+(7)	(9) Earnings (2)+(7)	(10) Earnings at 4% on Reserve	(11) Depreciation +Earnings (2)+(3)+(10)	(12) Earnings (2)+(10)
1	$10,000.00	$ 600.00	$ 758.68	$ 1,358.68	$ 1,281.77	$ 758.68	$	$ 1,358.68	$ 600.00	$	$ 1,358.68	$ 600.00
2	9,000.00	540.00	804.20	1,344.20	1,196.33	1,562.88	45.52	1,389.72	585.52	30.35	1,374.55	570.35
3	8,000.00	480.00	852.45	1,332.45	1,118.75	2,415.33	93.77	1,426.22	573.77	62.52	1,394.97	542.52
4	7,000.00	420.00	903.60	1,323.60	1,048.42	3,318.93	144.92	1,468.52	564.92	96.61	1,420.21	516.61
5	6,000.00	360.00	957.82	1,317.82	984.75	4,276.75	199.14	1,516.96	559.14	132.76	1,450.58	492.76
6	5,000.00	300.00	1,015.29	1,315.29	927.23	5,292.04	256.61	1,571.90	556.61	171.07	1,486.36	471.07
7	4,000.00	240.00	1,076.20	1,316.20	875.35	6,368.24	317.52	1,633.72	557.52	211.68	1,527.88	451.68
8	3,000.00	180.00	1,140.77	1,320.77	828.67	7,509.01	382.09	1,702.86	562.09	254.73	1,575.50	434.73
9	2,000.00	120.00	1,209.22	1,329.22	786.76	8,718.23	450.54	1,779.76	570.54	300.36	1,629.58	420.36
10	1,000.00	60.00	1,281.77	1,341.77	749.24	10,000.00	523.09	1,864.86	583.09	348.73	1,690.50	408.73
		$3,300.00	$10,000.00	$13,300.00	$ 9,797.27		$2,413.20	$15,713.20	$5,713.20	$1,608.81	$14,908.81	$4,908.81

mental assumption seems to be sound. The fact that results of the application of the assumption closely follow known facts tends to show that the gradual loss of the power of resistance with the passage of time has some bearing on the time of ultimate death. In other words, in human beings physical decay is a function of time. All that Makeham did was to add a factor to bring the element of chance into the formula. We know that in human experience such chance of accidental death plays but a small part and that most deaths are due to the gradual loss of power to resist destruction. As will be pointed out later, this is not true as to most of the physical property of a water utility. As to this property, there is no evidence that loss of service capacity is a function of time.

In working out their rates the insurance companies have studies of hundreds of thousands of human lives, classified and reclassified, revised and re-revised, with changes of conditions. Those rates are based, not on avera-- lives, but on the assumption that out of the large group which they cover at each age, a closely calculated number will die during each succeeding year. Two elements are needed to make the business sound—first, experience tables, showing the actual results of the forces assumed by Gompertz and Makeham, and second, large groups to be covered in each age division, so that by the law of probability, no risk will be assumed in the aggregate.

Do Utility Properties Fall Under the Law of Probabilities?

Let us check age-life depreciation of physical property against these elementary facts and principles.

First, do the properties of utilities have large enough groups of items to make the risks assumed negligible by the law of probabilities? Remember in this connection that in depreciation the group of customers assumes the position of an insurance company which agrees to pay annuities. The customer group is to pay to the utility such an annuity as will amortize the prepaid expense in the fixed capital asset accounts during the life of the property. The customer group pays the annuities and the shorter it estimates the life of the property to be, the higher the annuity must be. For that reason, its estimates must be sound. Are they sound in age-life depreciation?

Most groups of customers of a water company will be paying an annuity on one or a very few reservoirs; on one or very few filter plants; on one or very few pumping stations; on one or very few pumps of each type. Those are the facts, and since they are the facts, where is the justification for applying insurance company annuity principles to these groups of property? There is no such justification because the groups are too small. Even if for such types of property we had accurate and voluminous mortality tables, and even if for them it were true, which it is not, that depreciation is a function of time, it would still be unsound to apply the age-life depreciation figures worked out from such mortality tables to items of property in which the risk could not be spread because of the lack of large numbers of identical units in the property being studied. The application to such properties of insurance company annuity practice puts the customer group in a class with gamblers and not business men. So far as size of samples, with consequent spreading of the risk, is concerned, and to that extent only, insurance principles would apply to meters, service lines, mains and valves.

One prime objection to the use of mortality tables in estimating depreciation is that the data required are not available and at the best cannot be made available for many years. For the construction of a mortality table for any one type of water utility property, such as ten inch cast iron tar coated mains, complete data would have to be available as to the units of such mains installed during each year and as to the year, if ever, in which each of such identified units was retired from service. From such data, and only from such data, can unit service years be learned, and the average life expectancy of new main units be calculated. Only from such complete data can average life expectancy be distinguished from the very different thing, the median year, which is the year in which half of the units had passed from service. Only from such complete data can average life expectancy be distinguished from the mode year with which it is often confused. The mode year is the year of life of a group of units in which more units than in any other year are retired from service. Use of this year as the assumed total life ignores the fact the majority of the units may remain in service far beyond this mode year. It is a fact that in many depreciation studies made by advocates of age-life depreciation the mode year is confused with average life and that in such studies the mode year is used in the calculations as the assumed life. This is a serious and common error.

But even if the data were available and for any plant were worked into a scientific mortality table, such a table would not prove that retirements in the past were due to the passage of time. The mere record that certain retirements did take place in time in the past is not proof that those retirements were caused by the passage of time, and so the passage of time cannot be used for all property types to measure depreciation. Remember that mortality tables are a sound basis for estimating the life expectancies of large groups of individual human beings because of the sound assumption made by Gompertz that man's power to avoid death is reduced with the passage of each unit of time, and because most human deaths are due to this gradual loss of power to resist destruction. Contrary to these essential facts of human mortality, a relatively very small bulk of water utility property suffers service death by reason of the gradual reduction with the passage of time of its power to resist destruction. A very small part of a water utility plant is ever retired due to decay, disintegration, wear and tear. Most water utility retirements, measured in dollar volume certainly, and probably in numbers of units, are caused by inadequacy, obsoleteness or the action of public authorities. These influences may just as well come into force in the tenth as in the twentieth year of the life of the plant unit. They do not progress with time because they just happen independent of the passage or accumulation of time. That means that, contrary to human mortality experience, most retirements of physical property in a water utility are due to chance and the interplay of a number of influences which, while acting in the stream of time, cannot be measured in their cumulative effect by the passage of time. The bulk of the deaths of water utility physical property is caused by the type of influence corresponding in human mortality data to the element of chance added to the formula by Makeham.

So far as most water works physical property is concerned, depreciation cannot be proved to be a function of time. That being so, the only basis for the application of life experience mortality table technique to such property is lacking. With changes in managerial policy, with change in rate of growth of population served, with change in the tempo of invention, with change in materials installed, the experience of past retirements becomes of less and less significance.

It is submitted that until a relationship of cause and effect can be established between the passage of time and the actual loss in service capacity of physical property, due to all causes known to be in operation, age-life depreciation should not be recognized as to all types of property as the standard method of calculating depreciation for all purposes and under all conditions.

Since this paper was originally written in 1940, the American Water Works Association Committee on Depreciation has published the results of elaborate, carefully carried out and laborious studies on the actual mortality experience of many typical water supply systems. These studies were made under the able supervision of E. H. Aldrich. As was to be expected, the mortality experiences of these different systems as to mass items, such as meters, valves, hydrants and cast iron pipe, vary widely and demonstrate that any age-life depreciation method must be tailored to fit the plant experience. They also demonstrate that, assuming insurance company methods should be applied, the life expectancies are much greater than had been assumed, or, in the case of cast iron pipe, the mortality curves have not developed to points where they can be projected with assurance. In the case of cast iron pipe, these studies do indicate a vastly greater life expectancy than any previously considered.

Before I go on, let me repeat that I believe accrued depreciation should reflect loss in service capacity from whatever causes are known to be in operation and that depreciation expense should be estimated consistently with accrued. Neither the utility nor the consumers should be permitted to play both ends against the middle. I believe that, fairly applied, depreciation, based on a study of actual conditions and giving proper weight to all factors known to be in operation, can be and has been worked out and should be given more consideration in valuation studies especially. Such depreciation studies should be fairly considered, but that cannot be so long as some commissions shut their eyes and ears to the shortcomings of age-life depreciation and accuse all advocates of other systems of being unscientific and unfair because some companies were both in the past.

Depreciation Based on Study of Existing Conditions

In the remaining portion of this paper, thought will be given to methods of estimating both accrued and annual depreciation, based on a study of known conditions. These methods are advocated because they are based on the idea that depreciation is a physical and economic condition of utility property, and that this condition is a fact determinable by competent appraisers from an examination of all known relevant circumstances. These methods do not require the making of the assumption, as to all physical property, that loss of service capacity is a function of age. They are based in part on the sound assumption

that a competent engineer can determine the condition and the remaining usefulness of a piece of property without knowing how old it is. Before saying more, let me state that the methods here advocated will almost always indicate an amount for annual depreciation expense which is less than would be indicated by a resort to the age-life methods unless those methods reflect the true implications of the Aldrich studies mentioned above. While the depreciation expense is less than that indicated by age-life methods as usually applied, it is still adequate.

It is agreed that depreciation is loss of service capacity. Depreciation is, then, a fact to be determined as other facts are determined by an examination of all the evidence. As to the fact of loss of service capacity actually existing in a unit or group of units, complex and interconnected and acted upon by many forces, it is idle to assume that any one method or formula can be applied to all the units or groups of units. One method will be sound as to some and unsound as to others. The light bulb about to burn out and fail may look good, but the evidence in the records showing that it has been burning approximately the total number of hours for which its elements will live will indicate that the bulb has lost practically its entire service capacity. It should be depreciated by an age-life calculation certainly. The same thing is true of boilers. In these and a few similar cases, the physical facts are such that depreciation by the age-life method is sound.

Take another example. A slim bladed, well balanced meat slicer, made of the best modern cutlery steel, is presented for a depreciation study. Its age is unknown, but it is known that invention for hundreds of years has not been able to improve the design. There is no known force tending to make the knife obsolete, but it is very dull. What is its loss in service capacity? It is not as useful as a sharp knife of the same material and design, so it has lost some service capacity. Its loss in capacity may be measured by the cost of making it sharp and by a percentage loss in future capacity to reflect the fact that continued sharpening will ultimately use up the effective cutting blade. This was not age-life depreciation but a depreciation based upon a weighing of physical facts. The appraiser did not need to know the age of the knife or how many years it had yet to live.

Take the case of a lead pencil. It may be a perfectly efficient writing instrument when its writing length is half used up, but at that point it is certainly fifty per cent depreciated because its remaining economic usefulness is only fifty per cent of what it was when the pencil was new. Its service capacity is fifty per cent used up or lost. However, the depreciation is determined by inspection and the age of the pencil need not be known and no total life needs to be assumed. Its depreciation is a factual condition revealed by inspection.

Determination of the condition of buried pipe lines by engineering studies is neither difficult nor unusual and the results obtained by competent fair-minded engineers working independently of each other are so closely in agreement that the results must be sound.

Obsoleteness is a fact capable of determination. It may be partial or it may be complete, but for every type of water works property an honest, competent engineering appraiser can determine the extent of obsoleteness existing. He weighs all known factors tending to show obsoleteness. He compares operating costs, capital costs, reliability, flexibility, established governmental policies as to grade crossing eliminations, street widening, hump removals, all forces which can be called to his attention as being in operation, and giving them all their proper weight, he gets a sound factual determination of the loss in service capacity due to obsoleteness, inadequacy and the actions of public authorities.

Similar studies of all other forces known to be in operation and affecting the utility property are carried out, and as a result of these studies the appraiser is able to determine the amount of loss in service capacity of the property. He determines it as a fact as to the existing physical property.

Total depreciation of any utility property consists of two elements—first, there is the completed depreciation which is the amount of all the property of the company which has, in the past, ceased to be useful and been retired from service and taken out of the fixed capital accounts; second, the depreciation or loss of service capacity actually existing as of any date in property either still in service or still retained in the fixed capital accounts. Both elements of depreciation must be considered if sound and conservative results are to be obtained in calculating the proper amount to be set aside annually as depreciation expense. Depreciation expense and accrued depreciation, both based on actual loss in service capacity, must be determined consistently with each other if fairness to all is to be achieved.

Annual depreciation expense is the loss in service capacity suffered during the year. If the actual loss in service capacity is determined by study at the end of last year and if a similar determination be made at the end of this year, both as applied to property still in the Fixed Capital accounts, then the annual depreciation expense for this year is the increase in the dollars representing loss in service capacity during the year, plus the amount of retirements during the year.

In the same way we can find the total depreciation during the entire life history of the utility. At the beginning of that life history, the loss of service capacity in the new plant was zero, and from that fact it follows that the loss in service capacity in existing property through all the years of the plant life is simply the dollars representing loss in service capacity in existing plant as of this date. To get total depreciation we must add to this figure all retirements through all the years.

If existing property, actual loss in service capacity, and all retired property are all expressed in dollars of a uniform value, and if all property existing and retired be weighted for its actual years in service and averaged over the total completed years of service of the entire property, we then get the average investment in existing property and the average investment in abandoned and retired property. Since total depreciation, consisting of actual loss in service capacity of existing property, plus total retirements in the past, are both expressed in the same dollar values, this total, divided by the total age of the property, will give the average annual amount of depreciation or loss in service capacity. This last figure of average annual amount of depreciation, divided by the average investment in existing and abandoned property, will give the average annual rate of depreciation expressed in percentage. This percentage, applied to the undepreciated existing property, is the calculated amount to be set up for the immediate future for annual depreciation expense.

Annual depreciation expense so computed is based on exactly the same data as those used in determining actual loss in service capacity. The history of all retirements in the past is given its exact weight in estimating expense in the future. Obsolescence is given full weight in both calculations. Obsolete property is included in total loss of service capacity, either by inclusion in retirements or by inclusion in the engineering study of existing property or both. All obsolete property is thereby properly deducted from a rate base and the company forecasts its depreciation expense on the same basis. All of the depreciation, past, present and future, is based on facts revealed by a study of all the elements known to have brought about loss in service capacity of this particular company.

The engineers who make the studies of depreciation must be trained men. They must know construction methods and costs; they must know materials and labor; they must know machinery, water systems, purification systems; they must know how water companies operate and how accounts are and should be kept; they must understand economic factors affecting plant operations, costs and equipment; they must have information about applicable laws and regulations. Further, they must be fair-minded, honest-minded, judicial in their attitude. They must be so honest in their mental attitudes that they will be consistent from item to item and from case to case. Such engineers can and do make sound determinations of depreciation.

Such engineers will probably find that as to some items of property the only existing depreciation is that which can best be measured by the cost of restoring the item to its original condition of unimpaired economic usefulness. Items which are efficient, adequate in capacity and as to which no forces known to be in current operation seem to have caused obsoleteness or to be producing conditions which will necessitate retirement at a date which can be definitely fixed, but which items of property are in need of repairs or replacements of parts, have suffered a loss of service capacity, and hence are depreciated to some extent. If the making of the repairs or the replacement of parts will produce a plant item equal to one with unimpaired service capacity, then surely the cost of those repairs or replacements measures the accrued depreciation.

It will be objected that the repairs or replacements of parts if made will be charged to maintenance and that to include them in depreciation now would be a duplication. This is not a valid objection because, first, the maintenance expense has not been incurred in the past or this loss of service capacity would not have been suffered; and second, current maintenance can never keep a plant in condition of unimpaired service capacity. The accrued depreciation of this type is the difference between the plant as it is after maintenance expense and as it would be if it were possible at that point of time to restore it to unimpaired service capacity by marginal maintenance. Marginal maintenance might be defined as the cost of taking a normally maintained plant and bringing every element of it to a condition of perfect maintenance. Such marginal maintenance costs have not been included in expense in the past and in practice never can be incurred because there always will be a difference between a well maintained plant and a perfect plant. There is therefore no duplication of charges if we recognize such mar-

ginal maintenance as accrued depreciation for some plant items.

It is probable that an annual depreciation expense so determined from a study of the past and present of a water company will be found to be somewhat higher than will be needed for the indefinite future. This is for the reason that by its inclusion, as a factor, of all past retirements, it assumes that future depreciation expense will follow the history of the past. Since each step of progress in invention brings perfection nearer, and since the present trend in water works progress is in the direction of a prolongation of the service life of property now in service, rather than in the direction of a shortening of that life, it appears that an annual depreciation expense for the future, based in part on a history of past retirements of property, may be on the conservative side. It may be found to be higher than is necessary.

Conclusion

Unless we are all ready to abandon the idea of depreciation as being loss in service capacity and are ready to accept depreciation as being merely the mathematical amortization of prepaid expense, without reference to physical and economic facts, we should adopt those methods for determining the extent of the loss which bring results most nearly conforming with the facts actually existing.

Clay Pipe Mfr.'s Hold Meeting in Akron

The National Clay Pipe Manufacturers, Inc., an association of 44 of the nation's most important producers of clay pipe, met on June 11-13 in Akron, Ohio, to discuss the outlook for the industry during this year and 1948.

Amongst such things as discussion of trends in the clay pipe industry, the most effective publicity methods to adopt, marketing procedures, etc., possibly the development of chief interest to the readers of this magazine was the discussion of increasing costs of production. Out of this came the decision of member firms to refrain from raising prices on clay pipe as long as permissible or until the increased cost of labor leaves no alternative. It was pointed out that Federal statistics indicated that the present prices on clay pipe had risen only 10 per cent above 1926 prices, whereas the average for all other building materials is 78 per cent above 1926 prices.

Planning Water and Sewerage Systems for the Small Community

Last fall the Tennessee State Planning Commission issued a bulletin titled "Planning Water and Sewerage Systems for the Small Community." It is an excellent piece of work and deserves commendation and comment.

Beginning with a short chapter on "Now that Peace Has Come," in which the problems of postwar water and sewerage systems are considered, the report goes into detail on the community water supply, and the community sewerage system and financial aspects of both.

Under Water Supply the bulletin discusses what is good water and what is it worth; administration; construction; etc. In reference to the sewer system and sewerage treatment works, a chapter discusses plants; treatment of industrial wastes, the sewerage system and community development; etc.

A chapter on financial aspects covers preparation of the issue; whether serial or term bonds should be used; callability; and certain cautions to be remembered. This bulletin also contains a sample bond prospectus, sample sewer rental ordinance, and a summary of legislation relating to public water and sewerage utilities.

Local communities planning expansion of or new construction of water and sewerage facilities may find this bulletin of considerable interest in the preparation of their publicity programs. If copies are available, they may be obtained from the Tennessee State Planning Commission, 432 Sixth Ave., N., Nashville 3, Tenn.

Unique Annual Report Represents Good Public Relations

Out in the capital city of the Hoosier state, Hardin Pearcy is Supt. of the Meter Dept. of the Indianapolis Water Co. and Mr. Pearcy's annual report to the meter readers is a unique piece of good public relations.

Not just a compilation of figures, Mr. Pearcy's report with its humor is the kind of thing that improves relations with employees. The following excerpts will illustrate the point.

"In 1946, we find that the meter readers of our company walked the equivalent of one time around the world, or approximately 25,000 miles.

"23 injuries were experienced, 9 being occasioned by dog bites, or an average of 1 dog bite for every 2,777 miles or for each 100,000 calls. Probably this is a very poor record for the dogs, but it does constitute a very good record for you as you did encounter literally thousands of dogs on this journey.

"Naturally, such a trip as this, entering dark basements all day long and writing millions of figures in meter books, requires equipment in the matter of pencils and flashlights. If you worked the entire 12 months, each of you used the equivalent of a pencil 26 feet in length and enough batteries to fill a flashlight 40 feet long."

The effectiveness of this report as a factor in good public relations was multiplied many fold by its inclusion in the company's house organ **Water Lines**, Edited by John Kleinhenz, Publicity Director.

HYDRAULICS FOR THE PRACTICAL WATER WORKS MAN

The Tenth of a Series of Articles

The Orifice Meter

By ROBERT W. ANGUS, M.E.
Consulting Engineer
TORONTO, CANADA
(*Professor Emeritus of Mechanical Engineering, University of Toronto*)

TO COMPLETE the work on meters for closed pipes it is essential to discuss the orifice. The orifice, which has come so largely into use during recent years, is of such a nature that it may often be put into old pipe lines with very little trouble or expense. As used in a meter, the orifice is a circular hole bored in a clean, thin, smooth plate and usually set in the pipe so that it is central with the pipe axis (the case where it is set off-center is not included in this discussion). The hole must be carefully and accurately bored so that there is no burr on its edges, but the edges must not be rounded, and for that reason the orifice is referred to as "square edged."

The plate must have a thickness not over one-thirtieth of the pipe diameter, but it is evident that it must be stiff enough so that it will not vibrate. For the large pipes it may be necessary to use a thicker plate than that specified above, but where this is done the hole must be carefully bored and the down stream edge of it bevelled away at 45 degrees till the cylindrical part left has a length not over one-thirtieth of the pipe diameter. Since wear and rust must be avoided, the plates are often made of monel metal or stainless steel. An orifice of the kind described is shown set up in a pipe in Fig. 35 and should have at least ten feet of straight pipe on the upstream side of it.

The jet passing through the orifice shows marked contraction and reaches its minimum area of about 62 per cent of that of the bored hole at a distance of approximately the orifice diameter below the face of the plate, but this distance varies with the ratio of the orifice and pipe diameters. This contracted jet is usually referred to by its Latin name of "vena contracta," the latter term often being used to denote the section of the contracted jet closest to the orifice.

The positions of the pressure connections vary, but those in the figure

The Author

are a common arrangement and are designated "vena contracta taps," but sometimes flange taps are used, the holes for these being made at the pipe flanges close to the plane of the orifice. In all cases the taps are best located on the lower side of the line, and since the coefficients to be applied to the device will vary with the position of these pressure connections, care must be taken to see that the coefficients used fit the particular arrangement. The ratio d/D of the orifice to the pipe diameter usually varies from one-fifth to three-quarters, although other proportions are used.

The formula for discharge through the orifice is similar to that for the Venturi meter and for the flow nozzle, and if vena contracta taps are used, with the upstream tap far enough above the orifice (about one pipe diameter) to be clear of the disturbed part of the stream, the formula would be the same as that for a Venturi meter with its throat at section 3, although the coefficient used would not be the same in the two cases. Practical calculations, however, cannot be based on the area of the contracted jet, as there is no convenient meth-

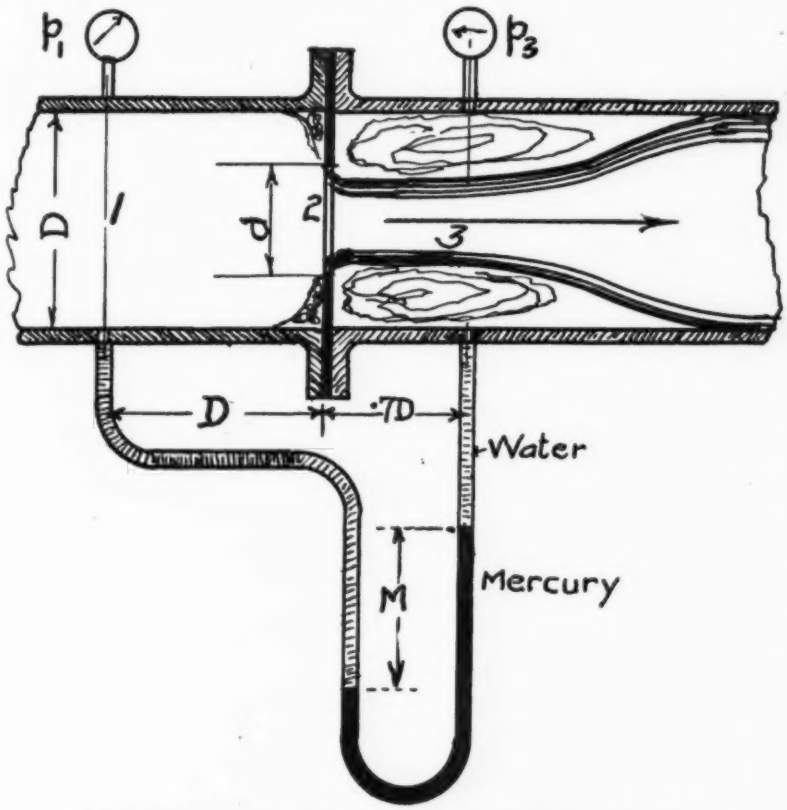


Fig. 35. Orifice in Pipe with Mercury Differential Gage

od of measuring this area in the plant; it is really a job for a research laboratory. In actual meters the diameter **d** is known to within one-one hundredth of an inch, and **D** is also known quite closely, and these two dimensions alone are involved in the practical formula. The coefficient obtained for the meter is based on these two diameters and does not include the vena contracta.

Discharge Through the Orifice

If the reader will again review the work on the Venturi meter he will readily see that the formula for the orifice should be

$$v_2 = \frac{1}{\sqrt{1 - \left(\frac{d}{D}\right)^4}} \cdot c\sqrt{64.3\,H}$$

where **H** is the drop in pressure $p_1 - p_3$ measured in feet of water, assuming water is the liquid flowing in the pipe. Were it not for the contraction of the jet, **c** would be very nearly unity as with the Venturi meter and the flow nozzle, but since in the orifice meter **c** takes account of the fact that the area of the jet is only about 62 per cent of that of the orifice, the orifice meter coefficient is in the neighborhood of 0.60. The meter companies have spent much time and money in getting accurate values of **c** and information on this point is given in the report of the Fluid Meters Committee of the Amer. Soc. of Mech. Engrs., referred to in Article IX of this series (June, 1947), and many details are also given in the Reference and Data Number of *Water and Sewage Works* for April, 1946 (p. 129). The differential **H** is usually measured by differential gage and recorders of the same type as is used on the Venturi meter are employed, the calibration of them being done in the way already described.

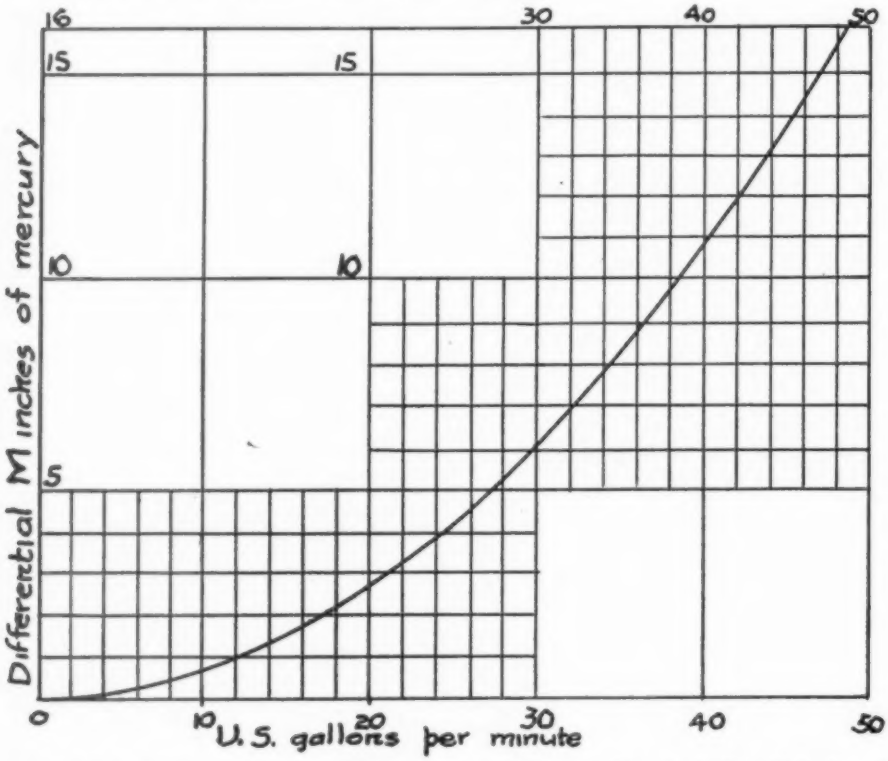


Fig. 36. Discharge Through an Orifice 1 in. in Diameter, Not Including Velocity of Approach Factor

(Multiply curve value by the square of the orifice diameter in inches and by the velocity of approach factor.)

Where permanent and accurate records of discharge are to be kept, the orifice and its recorder must be carefully and properly installed and the correct coefficient must be used. It is usually best to have the installations made by a meter manufacturer. The recording instrument must be bought in any event, as it is too difficult for ordinary people to make it. It may happen, however, that measurement of the discharge is only to be made temporarily and that results within about two or three per cent are close enough. In this case a coefficient of 0.60 will serve very well on pipes 2 to 14 in. in diameter if the orifice is between one-fifth and three-quarters of the pipe diameter and vena contracta taps are used. The orifice plate must be made, as already described, and the size of the orifice should be such that the differential will not exceed a 200 in. water column, or if a mercury differential gage is used on a water line it should not indicate over 200/12.6 or 16 in. (See Article IX, discussion of "Differential Gages," *W. & S. W.*, June, 1947.)

Suppose that it is desired to measure the water flowing through a 12 in. pipe, results within two per cent being close enough, and that it is possible to insert a plate with 6 in. orifice between flanges where there are 12 ft. of straight pipe upstream. To get the differential, one-quarter inch holes should be drilled through the bottom of the pipe, one of them 12 in. (one pipe diameter) above the upstream face of the orifice and the other 0.60×12 or 7 in. below the same face and the ends of these holes inside the pipe wall should be examined to see that there are no roughnesses around them. Usually ¼ in. piping is used to connect the drilled holes to the gage, but this ¼ in. pipe must not project through the inside of the pipe wall. If, after the gage has been connected up, it shows a differential of 15 in., then the drop in pressure across the orifice is $15 \times 1.05 = 15.75$ ft. of water (see Article IX), that is, **H** is 15.75 ft.

Referring to the formula given above, the velocity of approach factor

$$\frac{1}{\sqrt{1 - \left(\frac{d}{D}\right)^4}}$$

will first be calculated, and since **d/D** is 0.5, this factor is readily found to be 1.032. The velocity through the orifice is, therefore,

TABLE I
Velocities in Pipes

Pipe size (in.)	Actual diam. (in.)	Area (sq. ft.)	Velocity ft. per sec. for 100 U. S. gal. per min.	Pipe size (in.)	Area (sq. ft.)	Velocity ft. per sec. for 1,000 U. S. gal. per min.
1	1.049	.00600	37.1	4	.0873	25.50
1¼	1.25	.00852	26.2	6	.1963	11.33
1½	1.50	.01227	18.2	8	.349	6.37
2	2.067	.0233	9.6	10	.545	4.07
3	3.068	.0513	4.3	12	.785	2.83

1,000 U. S. gallons per minute = 1.44 million gallons per 24 hours. One cubic foot per second (1 cfs.) = 450 U. S. gallons per minute (450 gpm.)

$v_2 = 1.032\ c\sqrt{64.3\ H}$, which works out to 19.7 ft. per sec. for values of c and H of 0.60 and 15.75, respectively. Looking now at Table I herewith, the discharge is seen to be $1000 \times 19.7/11.33$ or 1738 U. S. gal. per min.

The measurement is convenient to make in general and the calculation is not difficult. The results cannot be automatically recorded without a proper device, but for occasional work it is no great task for an operating engineer to read the gage at regular intervals and mark down the results.

To assist in making such calculations, as are required in the above example, Fig. 36 has been prepared and although drawn on a small scale, may be used to give accurate results. It is calculated from the formula given for the meter using $c = 0.60$ and an orifice diameter of one inch, for which the area is 0.00545 sq. ft., and for this case the discharge is $0.00545 \times 0.60\sqrt{64.3\ H}$ multiplied by the velocity of approach factor. But as this discharge is in cubic feet per second, it is to be multiplied by 450 to give the corresponding rate in U. S. gallons per minute. If, further, the result is desired in terms of the reading on the differential gage, suppose the latter is denoted by **M** inches, then since **H** is 1.05 times **M**, the formula for discharge through an orifice one inch in diameter, with a differential reading of **M** inches on a differential gage using mercury and connected at vena contracta taps is: G = velocity of approach factor times $450 \times 0.00545 \times 0.60\sqrt{1.05M \times 64.3}$ gallons per minute, and when this is worked out it finally gives $G = 12.1\sqrt{M}$ times the velocity of approach factor.

The curve on Fig. 36 is calculated from the formula $G = 12.1\sqrt{M}$ and hence to apply it to a given actual case one would first read from the curve the quantity corresponding to the inches of mercury shown on the differential gage, and by multiplying this quantity by the square of the diameter of the orifice in inches and by the velocity of approach factor, the discharge in gallons per minute is found. For convenience a number of common values of the velocity of approach factor are as follows:

Ratio d/D	Velocity of Approach Factor
0.2	1.001
0.3	1.004
0.4	1.013
0.5	1.032
0.6	1.072
0.7	1.147

As an illustration of the use of the curve we might apply it to the case already given, for which the quantity on the curve corresponding to 15 in. mercury differential is 46.8 and the ratio **d/D** is 0.5, giving a discharge of $46.8 \times 6^2 \times 1.032 = 1738$ gallons per minute. The approach factor term has little effect where **d/D** is less than 0.4.

Great care must be observed in the use of the orifice for it is so easily changed that a mistake may be made as to the size in use. It is common practice to make the plate with a projecting tab on which the size of the orifice is distinctly marked and this is a great help. Any dirt on the face of the orifice plate or any rounding of the edge of the orifice may cause relatively large errors, usually by giving larger discharge than the formula indicates.

Orifice in an Open Tank

The orifice is often used in the side or bottom of an open tank and makes a convenient and accurate measuring device, where water can be permitted to flow through such a tank. The constant head tank with orifices is also often used to measure and control the feeding of chemical solutions to water, sewage, etc. An arrangement of tank with orifices is shown in Fig. 37, where a square edged orifice is placed in the vertical side of the tank, with its inner face flush with the wall of the latter, so as to give a smooth plane surface all around the orifice. An orifice is also shown in the bottom of the tank. The tank must be so large that the orifice is at no point closer than about two diameters from the side walls (and bottom also in case of the vertical side wall orifice), and the horizontal area of the tank should be at least ten times that of the orifice. For accurate work the depth of water above the highest point of the orifice must be at least three times the diameter of the latter, since under this condition the velocity at the center of the orifice is, without appreciable error, the average velocity of the stream as a whole.

Where sufficient care is taken to keep the water in the tank free from eddies and whirls, and the design and location of the orifice are correct, the jet from the orifice takes on the impressive appearance of a clear glass rod of the shape shown in Fig. 37 and it has no apparent motion whatever. The vena contracta (3 in., Fig. 37) is very nearly one-half the diameter of the orifice (**d**) away from the face of the orifice. Its area is almost exactly 62 per cent of that of the orifice, irrespective of its size or of the depth of water above it, which means, of course, that the diameter of the contracted jet is $100\sqrt{.62}$ or 78.7 per cent of that of the orifice. Taking the datum line through the center of the orifice and section 1 (Fig. 37) several feet back, where the velocity is negligible, it is seen that the only head at (1) is the pressure head p_1, which is usually designated by the letter **H** in this case. In the plane of the orifice at (2) the elevation is zero and the friction loss F_2 between 1 and 2 must be small because of the low velocity in the tank.

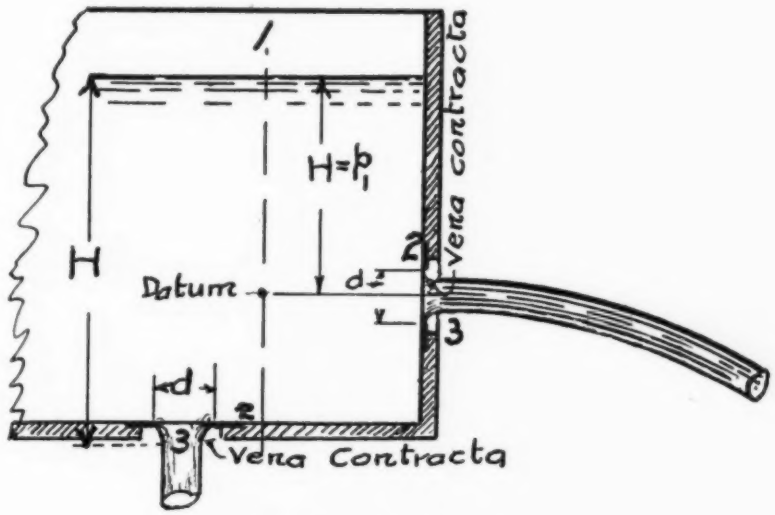


Fig. 37. Orifice In Open Tank

Formula for Discharge Through the Orifice

At the vena contracta the velocity is highest because the jet is smallest at this point, and since beyond this point, the size of the jet is found to be uniform, it is reasonable to conclude that the pressure at (3) is atmospheric. The head equation then gives:

$$H = p_2 + \frac{v_2^2}{64.3} + F_2 = \frac{v_3^2}{64.3} + F_3$$

where F_3 is the loss of head in friction from (1) to (3).

The orifice was one of the devices investigated by the early workers in hydraulics, and interest in it has never ceased. It has been found relatively easy to measure the exact diameter at (3) and by catching the flow in a weighing tank on scales the flow per second is obtained and consequently the velocity v_2 through the orifice is easily determined. All the measurements show that the *coefficient of discharge* $\frac{v_2}{\sqrt{64.3}}$ varies from 0.59 to 0.618 for round orifices from one to twelve inches diameter and for high and low values of **H**, as long as the conditions described at the beginning of this discussion are observed.

Taking a mean value of 0.61 for this coefficient and putting it in the last formula gives $v_2^2/64.3 = 0.37H$, and since it has already been stated that A_3/A_2 has a value 0.62, it follows that

$$v_3 = \frac{A_2 v_2}{A_3} = \frac{v_2}{0.62} = \frac{0.61\sqrt{64.3\,H}}{0.62} = 0.984\sqrt{64.3\,H}$$

If this value is put in the equation $H = v_3^2/64.3 + F_3$, it gives $H = 0.97H + F_3$, which means that the friction loss from section 1 in the tank to the vena contracta (3) is only 0.03H, a somewhat remarkable result when one considers the way the water is forced past the sharp edges of the orifice. The losses in contractions like this are very small.

It is a matter of interest, though of no great practical significance, that the pressure in the jet at the orifice (section 2, Fig. 37) is greater than atmospheric. This statement is evident when it is noted that F_2 must be less than F_3 and could, therefore, almost be neglected, but if its extreme upper value of $F_2 = F_3 = 0.03H$ is used, then

$$H = p_2 + \frac{v_2^2}{64.3} + F_2 = p_2 + (0.61)^2 H + 0.03\,H$$

from which $p_2 = 0.60H$. For an orifice under two feet head, the pressure in the jet in the plane of the orifice is, therefore, 1.2 ft. above atmospheric.

For the orifice, the discharge, expressed in cubic feet per second (Q), is

$$Q = A_2 v_2 = A \times 0.61\sqrt{64.3\,H} \text{ or } Q = 0.0267\,d^2\sqrt{H}$$

where the diameter of the orifice is **d** inches. (The areas are all in square feet, of course.)

The above formula is a most convenient one, since it may be applied to all liquids if they are not too viscous. The round or concentric orifice is, therefore, very frequently used for measuring oils and chemical solutions as well as water. For water works problems it is most convenient to have the discharge in gallons per minute, which is easily obtained by multiplying the cu. ft. per second discharge (**Q**) by 450. Since the discharge (**G**) in U. S. gallons per minute is $450 \times Q$, if this is worked out, it gives $G = 12.01d^2\sqrt{H}$, where **d** is the orifice diameter in inches.

The orifice is often placed in the bottom of the tank, as is also indicated in Fig. 37, but if the head equation is written out for this case it will be found that the head **H** must be measured from the plane of the vena contracta (3), as is also indicated on the diagram, since it is at this point that the pressure first becomes atmospheric. The accuracy in this case is not quite as great as for the vertical orifice in the side wall because the **exact** position of the vena contracta is uncertain.

It might be well to note in passing that if the orifice is made with well rounded edges, instead of the square edges discussed in this article, there would be no contraction of the jet and the coefficient of discharge would be almost unity. (In connection with this discussion of "Orifices" the reader is also referred to Article VII of this series in *W. & S. W.* for Feb., 1947, which discusses "Tank and Reservoir Discharge Openings" of various designs, including the plain circular orifice. This series of articles by Prof. Angus will continue.—Editor.)

PHILADELPHIA TO HAVE MILLION DOLLAR OZONATION PLANT

Being Installed to Remove Tastes and Odors from 36 MGD. Belmont Supply

The largest plant in the United States for the treatment of water with ozone is to be installed by Philadelphia at the Belmont Filter Plant.

Elbert J. Taylor, Chief of the Water Bureau, reports that contracts have been let for the ozone equipment to be supplied and installed by the Ozone Processes Div. of The Wellsbach Corp. of Philadelphia. It is estimated that the complete plant for the treatment of 36 mgd. will cost roughly $1,000,000 and is indicative of what a city is willing to spend in order to produce water of high palatability. As a matter of fact, the City Council has authorized the Water Bureau to spend up to $10,000,000 in its program of producing palatable water after many years of contending with a supply which at times has been highly unpalatable as the result of industrial pollution of the Delaware and Schuylkill Rivers, particularly the latter.

At Belmont Filters the ozone will be applied as pre-treatment ahead of the filters and post-chlorination will be applied to insure residual chlorine of from 0.1 to 0.2 ppm. in the distribution system.

At the Queen Lane Plant, with a capacity of 60 mgd., "break-point" prechlorination is planned for taste and odor control. The excess residual chlorine will be reduced with sulphur dioxide ahead of the filters and likewise facilities for the use of chlorine-dioxide treatment of the finished water are also being provided, as well as the application of activated carbon just ahead of the filters.

From what has been said here it is apparent that Philadelphia's Water Bureau is intent on seeing to it that the Philadelphia supply is to be rid of tastes and odors and made safe and palatable.

In all of this we are reminded of an editorial which appeared several years ago in this magazine. This editorial was in support of the claim and prediction of John Baylis of Chicago, who had stated that the day would come when the cost of producing a water of complete safety and high palatability would not longer be a barrier to the adoption of methods which would insure such a water continuously. Why not? Because the public would demand it and be willing to pay for it. In Philadelphia it looks as if this day has come.

MECHANICAL SEWER CLEANERS SIMPLIFY SEWER MAINTENANCE

Los Angeles Experiences Show Manpower Saving Plus Time Reduction and Higher Efficiency in Maintenance Operations at Lower Costs

By REUBEN F. BROWN
Superintendent
SEWER MAINTENANCE & OPERATION
LOS ANGELES, CALIF.

THE use of mechanical equipment in cleaning sewers or storm drains, pipe-lines, etc. seems essential to this writer in any well planned sewer maintenance program. In either a large or small sewerage system it is believed that the use of powered sewer cleaning equipment will reduce cost and increase operating efficiency, as it has on the Los Angeles system, in the following particulars:

1. By regular systematic cleaning.
2. By reduced sewer line stoppages.
3. By allowing use of full capacity of pipe lines, as designed.
4. By eliminating back-breaking hand rodding and conditions hazardous to personnel.

The Author

5. By not obstructing traffic and by speeding up operations.
6. By reducing the cost of pipe-line cleaning.
7. By making possible a well planned pipe-line cleaning program.

The City of Los Angeles has some 3700 miles of sewer and storm drain pipe-lines. Many are on a very flat gradient and settling out of solid materials causes retarded flows necessitating regular cleaning of such lines. Roots, grease, rags, rocks and sticks cause obstructions making manholes overflow. These have to be opened at frequent intervals to prevent serious health menaces caused by sewage overflowing on the street. In years past such stoppages had to be relieved by hand operations. This meant back-breaking manual labor and exposing the workers to all the dangerous and hazardous conditions found when working down in manholes and sewers.

Our Newest Power Driven Werko Sewer Cleaning Machine—1947 Model.

Los Angeles Purchased First Cleaning Machine 10 Years Ago —Two More Since

In 1937 the City of Los Angeles purchased a Werko Power Driven Sewer Cleaning Machine for the purpose of eliminating manual rodding of sewer lines and also to increase the effective use of personnel then employed. In 1940 a second Werko Cleaning Machine of a little larger capacity was purchased, giving greater efficiency in the work. In 1947 the third Werko Cleaning Machine was purchased, with additional improvement in operation and maintenance resulting.

These power driven cleaning machines operate by thrusting a continuous ⅝ inch steel rod through the line revolving it as it travels back and forth. Various types of cleaning heads and cutting tools are attached for the removal of scales, roots, grease, rubbish, etc. which cause stoppages.

Increased Efficiency from Regular Systematic Cleaning

In planning a year's work, to determine the required personnel and the necessary funds for the material needed, every engineer or superintendent in charge of sewer or storm drain pipe-line cleaning has listed in his records, or knows, locations that will need regular systematic cleaning; also the number of times per year that they will need to be cleaned to keep stoppages at a minimum. Formerly the sewer maintenance crews going regularly to these locations were not able in much less than a day's operation to completely clean the line and remove such stoppages or root growths as may occur. Through the use of the power driven cleaning machines, a crew may now set up at fifteen to twenty locations in a day and rod any where from 1500 to 2500 feet of pipe-lines. Such systematic mechanical cleaning of sewer and storm drain lines not only gives a better maintained sanitary sewer system but increases the efficiency of the personnel employed and spreads the work production load more evenly over the year. This results in reduced maintenance cost per foot of line over the entire pipe line system.

Sewer Line Stoppages Reduced

One of the greatest troubles in sewer maintenance on the Pacific Coast is the root growths seeking the moisture of sewers during dry seasons. These roots will enter main line sewers through poorly constructed pipe-line joints, or through even the smallest cracks caused by improper back filling, or from poorly hooked-on house connections from sewer to property line. These roots will continue to grow and increase in size until lines are actually cracked and shattered if these roots are not continuously removed by cutting and rodding of the lines. A list of such bad sewer locations should be set up and checked at regular intervals so that the bad sewer locations may be systematically cleaned and rodded. This will reduce root stoppages to a minimum. Also included in this list should be locations where deposits of heavy grease are experienced, and points where heavy industrial waste discharges cause stoppages in the line.

Root Troubles?
Just one of our prize specimens. This 120 ft. root strand from Mountain Oak was taken from a 6 in. line. Cleaning machine at manhole in distance.

"Exhibit AA."
It really required power to dislodge and remove this 129 ft. root mass which had quite a bulk at the point of entry into the sewer.

About 20 years ago the City of Los Angeles had from 1200 to 1500 sewer stoppages a year; or, on the average, better than 100 per month. By having a planned maintenance program for routine cleaning of these "bad locations" systematically, and the use of our modern mechanically operated sewer cleaning equipment these stoppages have now been reduced to about 10 a month, representing the impressive reduction of 90 per cent or better in stoppages.

Capacity of the Lines Maintained

One of the serious conditions in sewer lines is caused by allowing settleable materials to lay in the pipe and reduce thereby the capacity of such lines. Allowing a pipe to become partially filled or stopped-up starts bacterial action which creates septic conditions in the sewage, accompanied by sulphide production which causes deterioration of pipe-lines and masonry structures. Such a condition is most serious where cement pipe is used. Such pipe lines, where materials in the sewage flow has a tendency to settle out, should be cleaned at regular intervals. When mechanically operated equipment is used for cleaning lines, it is easy and inexpensive to clean, and the full capacity of the pipe is available for the purpose for which it was designed. Neglect of periodic routine cleaning of such conditions sometimes will necessitate the building of a new sewer line which would not have been needed if the old line had been properly maintained. Too much cannot be said about a preventive program or, as the saying goes "A stitch in time saves nine," for the regular systematic cleaning of sewer lines. Mechanical equipment helps make it possible to carry out such a program.

Eliminates Hand Rodding and Hazardous Conditions

Although hand rodding of pipelines cannot be entirely eliminated, when mechanical equipment is used personnel employed in such work will use it wherever possible in preference to any other equipment. It is a natural human trait to employ the easiest and quickest method possible when performing any hard, dirty, hazardous work. Mechanical power-driven equipment is not only more efficient; it does a more thorough job.

Our 1937 Model Werko Still Gives Efficient Service.
Operated by a three man crew. Note that traffic lanes are clear on both sides of the machine, thus not obstructing traffic.

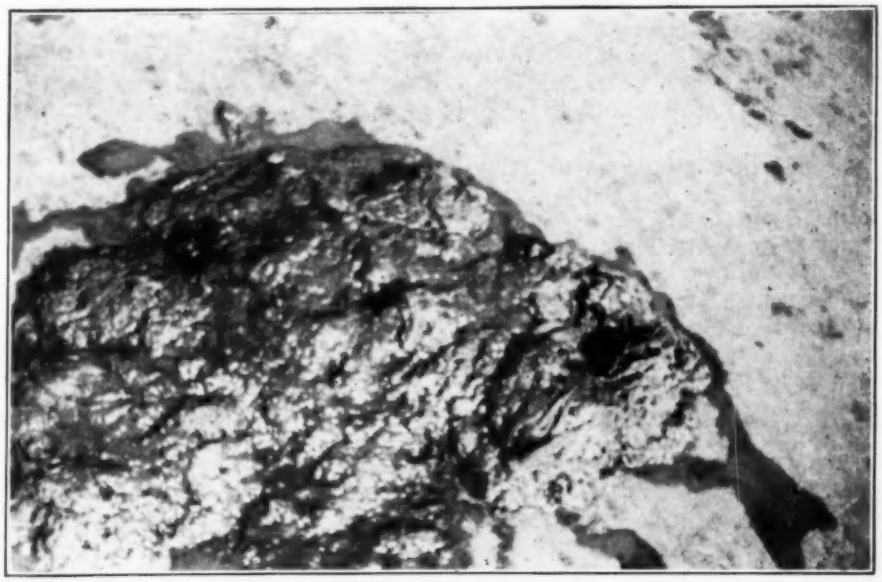
It has been found that, where lines were supposed to be rodded two or three times a year, once a year by the hand method would be claimed sufficient with plenty of excuses as to why it was impossible to enter the sewer line and rod by hand the other times. This is particularly true where the sewage flow is deep and dangerous gas conditions exist. The personnel employed on the cleaning of sewer lines soon learn that a well cleaned line will keep the air in manholes clean, with a minimum of danger due to oxygen deficiency. This is the result of a free flow of air by natural ventilation through the sewer system.

Does Not Obstruct Traffic and Speeds Up Operation

As the accompanying pictures reveal, the compact Werko Cleaning Machine does not obstruct traffic when operating through manholes even on busy streets. It can be quickly set up and dismantled in a few minutes. Even when manholes are located in between streetcar tracks, the sewer lines may be cleaned at almost any time, due to the ability of finishing the job quickly and going on to the next location. This avoids traffic delays and annoyance to motor vehicle drivers. A crew of three men are used in the operation of the equipment. (See pictures). The latest, most modern, machine has a reel capacity of between 800 and 900 lineal feet of flexible spring steel rod. This allows the cleaning of long distances from one setting and the ability to turn the machine about-face and clean the same distance in the other direction. In other words, it is possible to clean either upstream or downstream on the same manhole structure. This speeds up operations and allows upwards to 1000 feet of sewer to be cleaned from one setting of the machine.

Cost of Cleaning Reduced

Day after day use of mechanically operated equipment for the cleaning of sewers reduces the overall cost for sewer cleaning. The actual cost of wire used in operation is 3/1000 of a cent a foot of line cleaned. The yearly daily average for the cleaning of sewer lines is over 2,000 feet per day or a total of between 40,000 and 50,000 feet per month. The cost of upkeep of a machine and the personnel employed in its operation will average from three to four cents per foot of line cleaned. There are times when serious operation conditions are encountered and the cost per foot may increase but over a year's average for one machine, the cost per lineal foot has been around 3½ cents per foot. The present planned program in the City of Los Angeles will exceed 1,440,000 feet of machine cleaned sewer line each year. Our original Werko machine, purchased over ten years ago, is still operating at maximum efficiency.



A Typical Grease Accumulation Removed by Power Cleaning Machine.

Treatment of Cyanides

(A Correction!)

In the article on "The Determination of Cyanides" by T. R. Haseltine, who wrote in the May issue of *Water & Sewage Works*, there appears a picture of the Willow Run cyanide waste treatment plant. The caption under this picture, on page 190, states that "three 25-foot chimneys serve as exhaust pipes for the reaction tanks at the industrial waste disposal plant." Nicholas Herda, Utilities Superintendent of the Kaiser-Frazer Corp. at Willow Run, writes that these chimneys are 40 ft. high and that in his opinion "a 25 ft. exhaust stack would be dangerously low for cyanide waste treatment plants using this type of process."

DETERMINING THE EFFICIENCY OF COOLING TOWERS, SPRAY PONDS, OR SIMILAR COOLING DEVICES

By W. F. SCHAPHORST, M.E.
NEWARK, N. J.

Water is needed for cooling in refrigeration processes, and owing to the fact that water always has been abundant and is comparatively cheap it has been allowed to go to waste into the sewer. As a result cities have found it necessary to make restrictions regarding water consumption. The logical answer is to use water cooling and water saving devices such as the cooling tower, spray pond, etc.

In addition to air conditioning there is the Diesel engine and other internal combustion engines which must be cooled. Much water has been wasted into the sewer in this way and it is not at all uncommon, now, to find cooling towers being used in conjunction with Diesels. For these purposes the cooling devices usually pay for themselves in a short time and are well worth while.

Herewith is a chart, prepared by the writer, for determining cooling tower efficiency. If you have a cooling tower, or are contemplating the installation of a device of that nature, efficiency is important. The chart is used as follows:

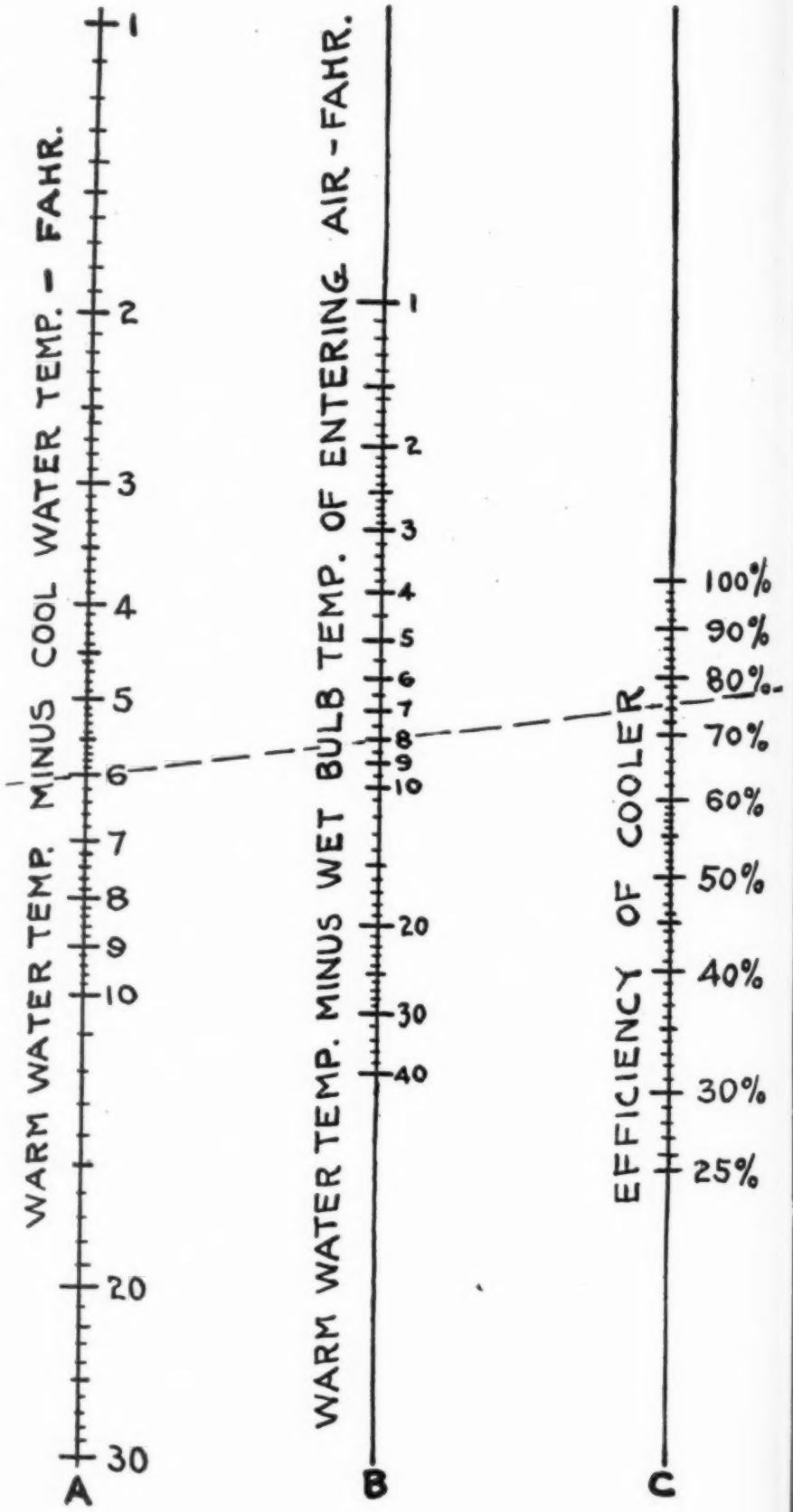
Subtract the temperature of the water after it is cooled from the temperature of the same water before cooling, and locate the difference in column A.

Then subtract the wet bulb temperature of the air entering the tower from the temperature of the water entering the cooling unit and locate the difference in column B.

Now run a straight line through the two located points in columns A and B and the intersection with column C gives the efficiency of the cooling tower, pond, etc.

For example, the dotted line drawn across the chart shows that if the temperature of the water before cooling is 88° and the cooled water temperature is 82°, the difference, 6°, is located in column A. If the wet bulb temperature of the air is 80°, subtract from 88° and locate the 8° in column B. The straight line then gives the efficiency of the cooling device in column C, as 75 per cent.

During summer months one should expect an efficiency of 65 to 70 per cent. If an efficiency of 90 per cent is reached by your device that may be regarded as very good. An efficiency of 35 per cent would be called poor. Much, of course, depends upon weather conditions.



Cooling Tower Efficiency Chart

THE HANDLING AND USE OF CHLORINE*

CHLORINE in commerce is a liquefied gas under pressure. All types of containers used in the transportation of chlorine, as well as all means of transportation, are strictly governed by the regulations and specifications of the Interstate Commerce Commission.

This liquefied chlorine in containers has both a liquid phase and a gas phase. The loading density of any container is limited by regulations to allow about 12 per cent gas space in a full container at 68° F. Temperature affects both the vapor pressure and the volume of liquid chlorine.

As the temperature of liquid chlorine increases, the chlorine gas above the liquid exerts a greater pressure (except at exceedingly low temperatures). For example, the gage pressure of a chlorine container is normally about 82 psi. at 68° F. and is about 140 psi. at 100° F.

The volume of liquid chlorine becomes greater as its temperature increases. Thus, in a full container at 100° F., the gas space is reduced to less than 8 per cent. The gas space would become completely filled with liquid if the temperature reached 153.4° F.

Because of these characteristics, chlorine containers should be handled with care and should never be heated. The greatest danger from chlorine occurs through the development of leaks, since strong concentrations of chlorine in the atmosphere may cause serious physiological effects.

Properties of Chlorine

1. Chlorine, gas or liquid, is neither explosive nor flammable.

2. Gaseous chlorine has a characteristic highly irritating and penetrating odor. This characteristic odor gives warning of the presence of chlorine in the atmophere before dangerous concentrations are attained. The greenish yellow color of chlorine gas makes it visible when high concentrations are present.

3. Gaseous chlorine is about two and one-half times as heavy as air and, therefore, if free, it flows to the floor or lower levels of a building.

4. Gaseous chlorine is only slightly soluble in water. WATER SHOULD NOT BE SPRAYED ON A CHLORINE GAS LEAK, because the corrosive conditions which result will make the leak worse and the heat supplied even by cold water will cause the liquid chlorine to change to gaseous chlorine at a faster rate.

5. Liquid chlorine is clear amber in color and is about one and one-half times as heavy as water. Under atmospheric pressure, liquid chlorine boils at about -30° F., changing to gaseous chlorine. Since it vaporizes with extreme rapidity if exposed to the atmosphere, liquid chlorine is rarely seen.

6. Upon vaporization, one pound of liquid chlorine forms about five cubic feet of chlorine gas; or, one volume of liquid chlorine yields approximately 460 volumes of chlorine gas. It is obvious that a liquid chlorine leak may be extremely hazardous as the quantity of chlorine discharged from a liquid leak will be many times greater than that discharged from a gaseous leak of the same size.

7. At ordinary temperatures, dry chlorine does not corrode steel or other common metals. In the presence of moisture, however, it is highly corrosive. Every precaution must be taken to keep the chlorine and chlorine equipment free from moisture. Pipe lines, valves, and containers should be tightly closed when not in use, since they will usually contain sufficient chlorine to quickly react with moisture from the air if left exposed.

Physiological Effects of Chlorine

1. Chlorine gas is classified as a respiratory irritant. In an atmosphere containing this gas, short, shallow breathing should be used. As chlorine is particularly irritating to persons afflicted with asthma and certain types of bronchitis, such persons should not be employed where it is possible to be exposed to chlorine.

2. When a sufficient concentration of chlorine gas is present in the atmosphere, it will irritate the mucous membranes, the respiratory system, and the skin. Relatively small amounts of chlorine can be detected because of the characteristic odor of the gas. Larger amounts cause irritation of eyes, coughing, and labored breathing. If the duration of exposure or the concentration of chlorine gas is excessive, it will result in general excitement of the person affected and will be followed by restlessness, throat irritation, sneezing, and copious salivation. The symptoms of advanced stages of exposure are retching and vomiting followed by difficult breathing. In extreme cases, the difficulty of breathing may increase to the point where death can occur from apparent suffocation. Chlorine produces no cumulative effects and complete recovery occurs from mild exposure. The physiological effects of various concentrations of chlorine gas are shown in Table A.

3. When liquid chlorine is exposed to the atmosphere, it vaporizes rapidly to chlorine gas and the resulting physiological effects will be those described above. Should liquid chlorine come in contact with skin or clothing, it may cause burns. Contaminated clothing should be removed immediately and the affected skin should be washed with large quantities of water.

TABLE A

Physiological Response to Various Concentrations of Chlorine Gas*

Effect	Parts of Chlorine Gas Per Million Parts of Air
Least detectable odor	3.5
Least amount required to cause irritation of throat	15.1
Least amount required to cause coughing	30.2
Least amount required to produce slight symptoms (of poisoning) after several hours' exposure	1.0
Maximum amount that can be breathed for one hour without serious effects.	4.0
Amount dangerous in 30 minutes to one hour	40-60
Amount likely to be fatal after a few deep breaths	1000

*From United States Bureau of Mines' Technical Paper 248, "Gas Masks for Gases Met in Fighting Fires."

Chlorine Containers

Liquid chlorine is shipped in various sizes of cylinders containing from 1 to 150 pounds of chlorine; in ton containers containing 2000 pounds of chlorine; in multi-unit tank cars carrying 15 one-ton containers; in single unit tank cars containing 16, 30, 55 tons of chlorine; and in tanks on barges.

Cylinders

1. Chlorine cylinders are of seamless steel construction and comply with the specifications of the Interstate Commerce Commission. They are equipped with an approved type of cylinder valve. Fig. 1 and 2 show cross sections of such valves. A protection hood is provided to cover the valve except when the cylinder is being emptied.

2. Special note should be made of the fusible metal plug in the valve. This plug is a safety device which has been designed to soften or melt between 158° and 165° F., allowing the contents of the cylinder to

*Reproduced from the *Chlorine Manual* of The Chlorine Institute.

USE SPECIAL WRENCH ON VALVE STEM, PACKING NUT, AND OUTLET CAP. ALL TIGHTEN CLOCK-WISE.
FUSIBLE PLUG
SPECIAL 3/4" STRAIGHT THREAD

Fig. 1—Chlorine Institute Standard Cylinder Valve Poured Type Fusible Metal Plug

USE SPECIAL WRENCH ON VALVE STEM, PACKING NUT, AND OUTLET CAP. ALL TIGHTEN CLOCK-WISE
FUSIBLE PLUG
SPECIAL 3/4" STRAIGHT THREAD

Fig. 2—Chlorine Institute Standard Cylinder Valve Screwed Type Fusible Metal Plug

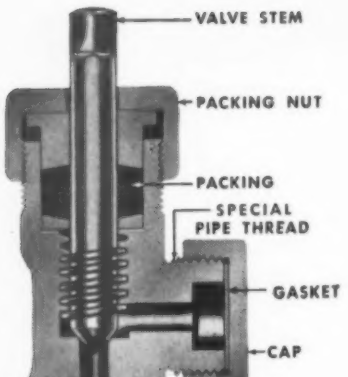


Fig. 3—Standard Ton Container Valve

discharge. The fusible plug is below the valve seat and cannot be controlled by the valve. It is very important not to tamper with the fusible metal plug under any circumstances. Two types of fusible plugs are in general use in cylinder valves as shown in the illustrations, Figs. 1 and 2.

Ton Containers

3. The chlorine ton container is a steel cylinder about 80 in. in length and 30 in. in outside diameter, complying in construction with the specifications of the Interstate Commerce Commission. Each end is dished, forming a chime which is crimped inward. The chime provides a substantial grip for hooks used in handling the containers. Each container is equipped with two valves which are located in one end near the center. Fig. 3 shows a cross section of such a valve. These valves are protected by a removable steel hood except when the container is being discharged.

4. The valves are identical and are connected inside the containers to eductor pipes as shown in Fig. 4. Thus, with the container lying on its side and the valves in a vertical line (one above the other as illustrated in the figure), the lower valve will discharge liquid chlorine and the upper valve will discharge chlorine gas from above the liquid level.

5. The valves are the same as cylinder valves, except that the ton container valve has no fusible metal plug and some containers are equipped with valves having slightly larger ports to provide for quicker discharge. The ton container is equipped with six fusible metal plugs, three in each end. The metal in these plugs has been designed to soften or melt between 158° and 165° F., allowing the contents of the container to discharge. It is very important that fusible plugs should not be tampered with under any circumstances.

Tank Cars

6. Liquid chlorine tank cars comply with Interstate Commerce Commission specifications. The tanks are constructed of welded steel and are provided with a covering of insulation which is in turn protected by a light steel jacket.

7. At the center on the top of the car is a circular steel housing, referred to as the dome, which contains all the valves on the tank. The two angle valves located on a line parallel with the length of the tank car are always arranged so that they will discharge liquid chlorine. Eduction pipes extending to the bottom of the tank are connected to these valves. Fig. 5 and 6 show cross sections of such valves. The two angle valves at right angles to the length of the car will deliver chlorine gas. (Note: On 55-ton tank cars, one of these gas valves has been replaced with a second safety valve.) All angle valve outlets have one-inch standard tapered female pipe threads and these outlets are protected by one-inch plugs when not in use.

8. The safety valve is located at the center of the dome. On ICC 105A300 tanks, the valve is set to be vapor-tight at 180 psi. On ICC 105A500 tanks the valve is set to be vapor-tight at 300 psi. Consumers must never disturb safety valves.

9. Check valves are located in the eduction pipes under each of the liquid valves. The function of the check valves is to shut off the flow of chlorine in case there should be a very rapid increase in the flow of the liquid, such as might be caused by too rapid opening of the discharge valve or a rupture in the piping system. Check valves may also be located below the gas valve outlet.

Tank Barges

10. Tank barges and their chlorine tanks must comply with the Bureau of Marine Inspection and Navigation, U. S. Department of Commerce Regulations. The tanks are of welded steel construction and are not insulated. At the top and center of each tank there is a valve dome. The dome valves are of the type and arrangement of those on a 55-ton tank car, see "Tank Cars." The safety valves are set to be vapor-tight at 300 psi. Barges and their unloading are of a special nature and all details relating to them should be referred to the chlorine producer having such equipment.

Handling Chlorine Cylinders and Ton Containers

The following rules are recommended for handling, storing, and using chlorine containers. Where the word, "container," is used in the following paragraphs, it applies both to ton containers and to all cylinders.

1. IN AN EMERGENCY, TELEPHONE THE CHLORINE MANUFACTURER WHOSE NAME APPEARS ON THE CONTAINER. The name and address of the manufacturer and/or nearest chlorine producer should be posted in the office of the person in charge of chlorine handling, in the first aid room, and in the office of the plant manager.

2. Canister gas masks of a type approved by the U. S. Bureau of Mines for chlorine service should always be readily available where chlorine is being stored or transported or used. Gas masks should be located outside the probable area of contamination so that it will be possible to reach them in case of emergency. Where chlorine is used over wide areas, masks should be available in several locations.

3. Gas masks of the canister type do not supply oxygen; they absorb the chlorine present in the air leaving clean air to breathe. Where the chlorine content of the air is greater than 1 per cent, a self-contained oxygen breathing apparatus, or a fresh air hose mask should be used. All personnel that may be required to use gas masks should be properly instructed and required to practice their application and use. See National Safety Council Pamphlet No. 64, "Respiratory Protective Equipment."

4. It is illegal to ship cylinders containing chlorine unless they are loaded by or with the consent of the owner of the cylinders.

5. Never mix chlorine and another gas in the container.

6. It is illegal to remove or change the numbers or marks stamped on the containers without written authority from the owner, and written notification to the Bureau of Explosives, 30 Vesey Street, New York 7, N. Y.

7. It is illegal to ship a leaking container, whether full or partially full. It is illegal to ship chlorine in containers that have been exposed to fire. Consult your supplier for advice under these circumstances.

Moving

1. Never drop containers or permit them to strike each other with any force.

2. Never use a lifting magnet or a sling (rope or chain) when handling containers. Hoisting should be avoided as much as possible. Where hoisting is necessary, the use of safe lifting clamps is recommended. A suitable lifting clamp for handling chlorine ton containers is illustrated in Figure 7.

3. To move cylinders about, use a hand truck properly balanced and preferably with a clamp support at least two-thirds of the way up the cylinder.

4. Consult your supplier for detailed information regarding the unloading of ton containers.

Storing

1. All containers should be stored in a cool place and protected against external heat sources.

2. Never store containers near combustible or flammable materials. Chlorine containers should be segregated.

3. Containers should not be stored where they are exposed to continuous dampness.

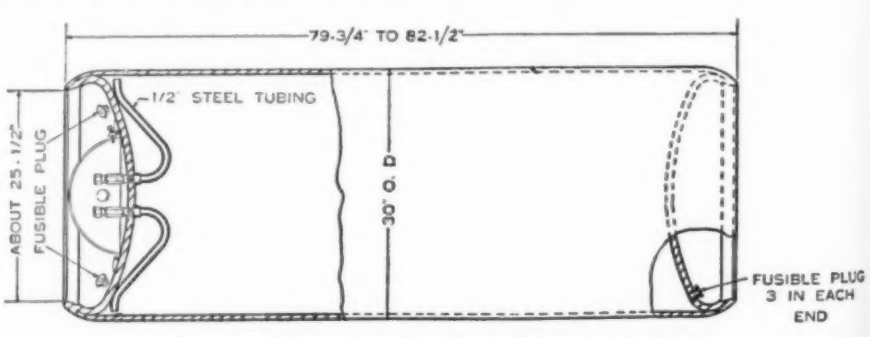


Fig. 4—Chlorine Ton Container, End and Side Views

4. Cylinders should be stored in an upright position. Ton containers should be stored on their sides on a level rack which may be constructed of I-beams or two railroad rails properly supported a few inches off the ground.

5. Valve protection hoods on ton containers and cylinders should always be kept in place except when containers are being emptied. Do not hoist cylinders by the hood.

6. Store full and empty containers in different places to avoid confusion in handling them. It is good practice to tag empties.

7. Do not store containers near elevators or gangways or in locations where heavy objects may fall and strike them.

8. The storage room should be well ventilated, and the containers so arranged that any container can be removed with a minimum of handling of other containers. Where practical, the storage room should

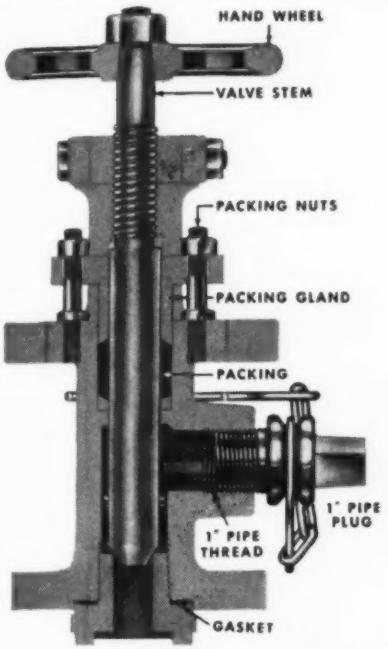


Fig. 5—Chlorine Angle Valve for Tank Cars

be fireproof. Storage in subsurface locations should be avoided.

9. Containers stored out of doors should be protected against direct exposure to the sun and against accumulation of snow or other material that may build up around them. They should be kept clean and should be inspected regularly.

10. Never store containers or place leaking containers where the fumes can enter a ventilating system.

Using

1. Use containers in the order in which they are received.

2. Never tamper with the safety devices on containers.

3. Open container valves slowly. The use of large wrenches or pipe wrenches will damage the valves. One complete turn of the valve stem in a counterclockwise (lefthand) direction opens the valve sufficiently to permit maximum discharge. Do not use a wrench longer than 6 inches on a container valve.

4. In making a connection to the valve outlet, clamps and adaptors are recommended. In case threaded connections are used, make sure that the threads on appliances and unions are the same as those on container valve outlets. Never force connections that do not fit. The outlet threads on the valves of containers are not tapered pipe threads.

5. Containers or valves should never be altered or repaired by the consumer.

6. Gas leaks around the valve stem may usually be checked by tightening the packing nut.

7. To test for chlorine leaks: Attach a cloth to one end of a stick, soak the cloth with ammonia-water, and apply to the suspected area. A white cloud of ammonium chloride will result if there is any chlorine gas leakage.

8. As soon as containers are empty, close their valves, disconnect, and test for chlorine leaks as described in par. 7 above, at the valve outlets. If no leakage is indicated, apply cap nuts to valve outlets, and attach valve protection hoods securely in their proper places. These fittings should always be kept in place except when the container is being emptied. The open end of the line leading from the container should be plugged or capped immediately to keep moisture from entering the system.

9. Return empty containers promptly.

10. Use only reducing valves and gages designed for chlorine. Consult the chlorine producer for details.

11. Never apply heat directly to any container. Containers should be discharged in a room which has a temperature of about 70° F. If the rate of gas evolution from a single container is not sufficient, consult your chlorine or chlorine equipment supplier for detailed information.

12. Cylinders of 150 pounds capacity or less will deliver chlorine gas when unloaded in an upright position and will deliver liquid chlorine when unloaded in an inverted position. The ton containers in a horizontal position and with the valves in a vertical line (one above the other as shown in Figure 2) will deliver liquid chlorine from the lower valve and chlorine gas from the upper valve.

13. If chlorine is being absorbed in a liquid, there is a tendency for the liquid to suck back into the cylinder or container due to creation of a partial vacuum when the cylinder or container becomes empty. This should be avoided as it has resulted in numerous accidents. Consult your chlorine or equipment supplier before proceeding with this operation.

14. Always empty cylinders and ton containers on a scale, in order to know at all times the amount of chlorine in the cylinder or ton container.

Handling Chlorine Tank Cars

1. The following special rules are recommended where chlorine is being handled in tank car quantities. These rules are in addition to those of a general nature set forth above, and which are applicable to all types of chlorine container handling.

2. Single unit cars must be unloaded only on a properly protected private track of the consumer, or on a leased track, in accordance with regulations of the Interstate Commerce Commission. In the case of multiple unit cars, where no private track is available, the ton containers may be removed from the under frame at a public siding if in accordance with Interstate Commerce Commission regulations.

3. Switch tracks on which chlorine cars are placed for unloading should be devoted solely to this purpose.

4. When a chlorine tank car is spotted on a siding for unloading, brakes must be set and wheels blocked. Interstate Commerce Commission regulations require the following: "Caution signs must be so placed on the track or car as to give necessary warning to persons approaching car from open end or ends of siding and must be left up until after car is unloaded and disconnected from discharge connection. Signs must be of metal, at least 12 by 15 inches in size and bear the words, 'STOP—Tank Car Connected,' or 'STOP—Men at Work,' and word, 'STOP,' being in letters at least 4 inches high and the other words in letters at least 2 inches high. The letters must be white on a blue background."

5. When tank cars are located on a dead end siding, the cars should be protected on the switch end by a derail. If on an open siding, derails should be provided at both ends. Keys for the derails should be in charge of a responsible person.

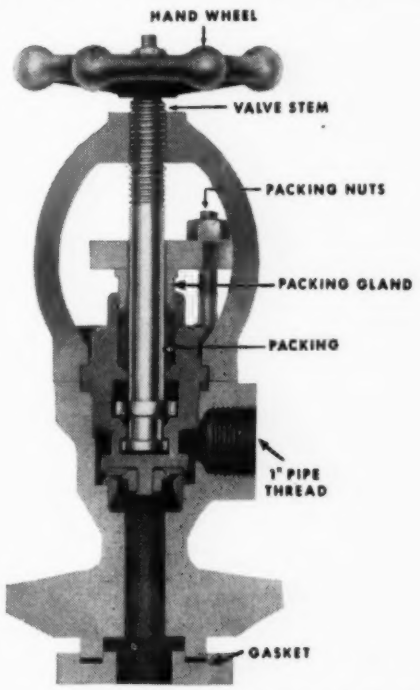


Fig. 6—Chlorine Angle Valve for Tank Cars

6. Unloading of single unit chlorine tank cars should be done through a flexible metal connection. (Note: Owing to the varying nature of locations of single unit tank cars placed for unloading, and to the length, arrangement, and other features of the unloading line from the tank car, no general specification for the unloading line is practical. For all details relating to the unloading line, consult the chlorine producer.) A flexible connection, however, should not be depended upon as a safety factor in case of a bump by switching operations during unloading. (Note: Derails should be in place as stated in paragraph 4 above, and red lanterns should be suitably placed if unloading is done at night.) Unloading, connecting, and disconnecting operations should be performed only in well-lighted places by reliable persons who are properly instructed and made responsible for operations and who are equipped with chlorine gas masks.

7. Tank car outlet valves should be kept closed when operator of chlorine line is not on duty. The pipe line beyond the tank car valve should not be left full of

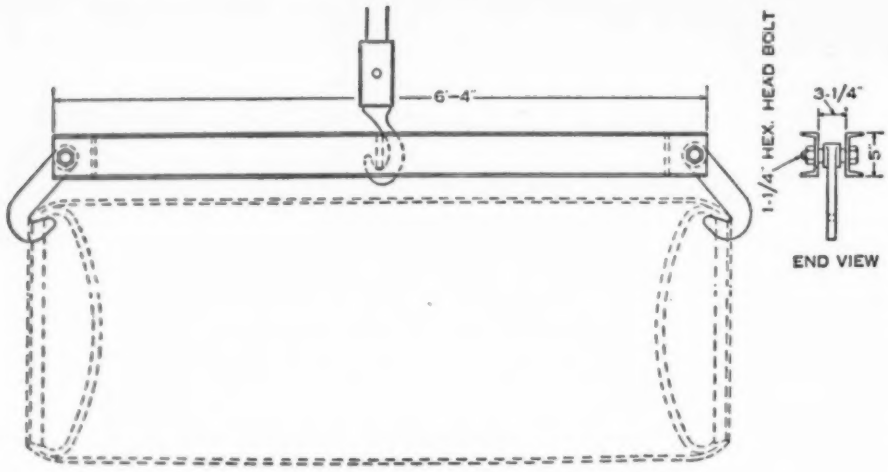


Fig. 7—Lifting Clamp for Chlorine Ton Containers

liquid chlorine during shut-down periods because trapping of liquid chlorine may result in broken lines and leakage.

8. When ready to discharge liquid chlorine from a single unit tank car, open tank car liquid angle valve slowly about two turns and control chlorine flow with regulating valve on end of unloading line.

9. If the check valve closes and liquid chlorine will not flow, it may be released by closing the discharge valve completely and leaving it closed until the metal ball in the check valve falls back into place. A noticeable click will be heard when this occurs.

10. It is illegal to ship a defective or leaking chlorine tank car. If a tank car is in bad order or if there is an accident, telephone the car owner or the nearest chlorine plant for assistance.

11. Heat must never be directly applied to tank cars. It may, however, be desirable in some locations which are subject to low winter temperatures, to unload the tank cars in a shed maintained at 70 to 75° F. In certain cases, however, particularly in winter weather with its low outside temperature, the pressure in single unit cars may not be adequate and it may then be necessary to increase it by the addition of dried compressed air to secure the rate of discharge desired. Only thoroughly dried clean air may be used for this purpose and it should be supplied by a separate air compressor which is used only for this service; an existing compressed air system should never be connected to the chlorine tank car. The air drier must be of suitable capacity to supply the full requirements and it must be maintained in proper operating condition. Consult the chlorine producer for all details relating to the application of dry air to single unit tank cars.

12. If the use of chlorine is at an elevation materially above that of the tank car, high pressure will be required in the car to force the liquid to the higher elevation. It is much safer to locate a chlorine evaporator at the elevation of the tank car and pipe the gaseous chlorine to the higher elevation. Consult the chlorine producer for all details relating to the design and use of evaporators.

Chlorine in Public and Semi-Public Buildings

Chlorine is one of the standard agents for disinfecting swimming pool water. The use of liquid chlorine for this purpose at indoor swimming pools should be recognized as potentially hazardous. Indoor swimming pools are usually located below ground level where, in the event of a chlorine leak, access to the chlorine cylinders and chlorinating equipment may be difficult. It is recommended that special safety precautions be provided where liquid chlorine must be stored or used in public and semi-public buildings.

Employee Protection

Emergency Measures

1. These suggestions are based on the experience of chlorine producers, and are presented as helpful information on the handling of chlorine. It should not be assumed that every acceptable safety procedure is contained herein, or that abnormal or unusual circumstances may not require additional procedures.

2. *As soon as there is any indication of the presence of chlorine in the air, steps should be taken to correct the condition. Chlorine leaks never get better. Chlorine leaks always get worse if they are not corrected promptly. Telephone your chlorine supplier or any chlorine producer if you need help.*

3. Keep on the windward side of the leak and higher than the leak.

4. When a chlorine leak occurs, authorized, trained personnel equipped with gas masks should investigate. For recommendations relating to gas masks, see Handling Chlorine, Cylinders and Ton Containers par. 1, 2 and 3. All other persons should be kept away from the affected area until cause of the leak has been discovered, and the trouble corrected. If the leak is extensive special effort must be made to warn all persons in the path of the fumes.

5. Where a leak occurs in equipment in which chlorine is being used, the chlorine container valve should be closed immediately.

6. If a chlorine container is leaking in such a position that chlorine is escaping as a liquid, the container should be turned so that chlorine gas escapes. The quantity of chlorine escaping from a gas leak is about one-fifteenth the amount that escapes from a liquid leak through the same size hole.

7. Do not apply water to a chlorine leak. The application of a stream of water to a chlorine leak is hazardous and makes the leak worse due to the corrosive action of chlorine and water.

8. If a chlorine leak occurs in transit in a congested area, it is recommended that the conveyance keep moving if possible until it reaches an open area, where the escaping gas will be less hazardous. If a chlorine leak occurs in transit and the conveying vehicle is wrecked, the container or containers should be shifted so that chlorine gas is escaping. If possible, the containers should then be transferred to a suitable conveyance and transported to the open country.

9. Pin-holes leaks in cylinders and ton containers may sometimes be temporarily stopped by driving a tapered hard-wood peg or metal drift pin in the hole. The container should be turned so that only gas is escaping before attempting to stop the leak. Extreme care should be exercised in driving in the plug, as the wall area surrounding the hole may be thin and crumble, thereby making the leak worse. When this emergency measure is taken, the cylinder must always be emptied of its contents as quickly as possible.

TABLE B

Recommended Alkaline Solutions for Absorbing Chlorine

Chlorine Container Size—Pounds Net	Caustic Soda — Pounds 100%	Caustic Soda — Water Gals.	Soda Ash — Pounds	Soda Ash — Water Gals.	Hydrated Lime — Pounds	Hydrated Lime — Water Gals.
100	125	40	300	100	125	125
150	188	60	450	150	188	188
One Ton	2500	800	6000	2000	2500	2500

10. At regular points of storage and use, emergency preparations for disposing of chlorine from leaking cylinders or ton containers should be made. Chlorine may be absorbed in caustic soda, soda ash, or hydrated lime solution. Caustic soda is recommended as it absorbs chlorine most readily. The proportions of alkali and water preferred for this purpose are given in Table B.

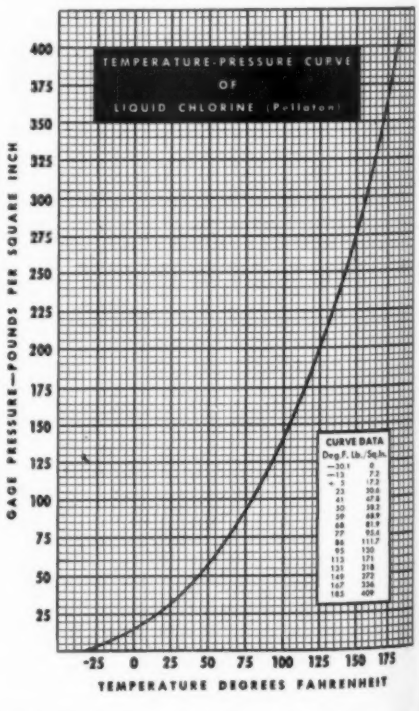


Fig. 8—Temperature-Pressure Relation of Liquid Chlorine

11. A suitable container to hold the solution should be provided in a convenient location. The chlorine may be passed into the solution through an iron pipe or rubber hose properly weighted to hold it under the surface. Discuss the details of such preparations with your chlorine producer.

Prophylactic Measures

The following prophylactic measures are recommended for persons who may be exposed to chlorine.

Prophylaxis, 1. Provide physical examinations including chest X-ray of applicants and of employees handling chlorine.

Prophylaxis, 2. Provide instructions and approved gas masks for all employees handling chlorine.

First Aid Measures

The following first aid measures are recommended for persons exposed to chlorine:

First Aid, 1. Carry patient from gas area. Patient should preferably be kept in a warm room (about 70° F.). Supply blankets if necessary. Keep patient warm and quiet. Rest is essential.

First Aid, 2. Place patient on back with head and back elevated.

First Aid, 3. CALL A PHYSICIAN IMMEDIATELY.

First Aid, 4. Splashes of liquid chlorine and chlorinated water destroy clothing, and if such clothing is next to the skin will provide irritation and acid burns. In such cases remove clothes and keep patient warm with blankets.

First Aid, 5. Carbon dioxide and oxygen mixture with not to exceed 7 per cent of carbon dioxide may be given. This mixture, ready prepared, and sold with the necessary apparatus, can be administered intermittently for periods of two minutes followed by two-minute rest periods over a total period not to exceed thirty minutes. Instructions of the purveyor of the gas apparatus should be carefully obeyed. If carbon dioxide and oxygen mixture is not readily available, oxygen alone may be used.

First Aid, 6. Milk may be given in mild cases as a relief from throat irritation.

First Aid, 7. If breathing has apparently ceased, start immediately the artificial prone pressure method of resuscitation (Schafer). Do not exceed 18 movements per minute.

First Aid, 8. Provide First Aid as may have been prescribed for emergencies by your company physician pending his arrival.

Chemical Characteristics and Physical Properties of Chlorine

Chlorine gas was discovered in 1774 by C. W. Scheele, a Swedish chemist, but he regarded it as a compound substance. The gas was first liquefied by Thos. Northmore in 1805. It was identified as an element in 1810 by Sir Humphrey Davy, who proposed the name chlorine and the symbol Cl from "chloros," the Greek word meaning green.

The chlorine of commerce is usually manufactured by the electrolysis of a solution of sodium chloride or potassium chloride. Gaseous chlorine so produced is dried and purified, then is liquefied by compression and refrigeration.

The following list describes some of the important chemical and physical characteristics of chlorine. The source of all data is given in Section N, page 30, of *The Chlorine Manual.*

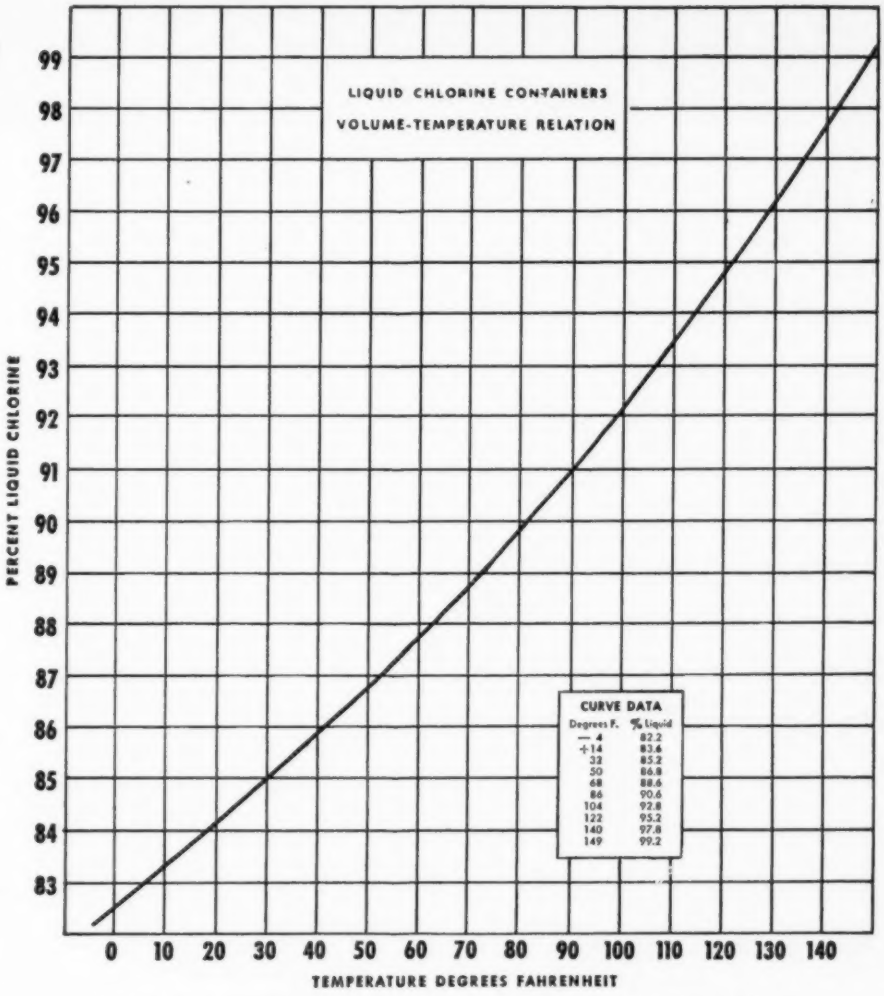


Fig. 9—Temperature-Volume Relation in Liquid Chlorine Containers

Action on Metals

At ordinary temperatures dry chlorine, gaseous or liquid, does not attack copper, iron, lead, or steel. Moist chlorine is very corrosive to all common metals, but gold, platinum, and silver are resistant. At temperatures below 150° C. (302° F.), tantalum is totally inert to wet or dry chlorine. At low pressures moist chlorine is frequently handled in earthenware, glass, or porcelain equipment; special high silica iron alloys, Monel, and Hastelloy "C" also exhibit good resistance.

Atomic and Molecular Data

The atomic and molecular characteristics of chlorine follow.

Atomic symbol:	Cl
Atomic weight:	35.457
Molecular symbol:	Cl_2
Molecular weight:	70.914

1 gm. mol. of chlorine = 70.914 gm.

Boiling Point

—34.5° C. (—30.1° F.). The temperature, under 1 atmosphere pressure, at which liquid chlorine boils or the gas liquefies. Alternate term is liquefying point.

Color

Gaseous chlorine is greenish yellow in color. Liquid chlorine is clear amber in color.

Critical Pressure

76.1 atmospheres, or 1118.7 lb. per sq. in. absolute pressure. The vapor pressure at the critical temperature.

Critical Temperature

144° C. (291.2° F.). The temperature above which chlorine exists only as gas, no matter how great the pressure.

Density, Gaseous Chlorine

1 liter of dry chlorine weighs 3.214 gm. at 0° C. (32° F.) and 1 atmosphere pressure.

Density, Gaseous Chlorine

1 liter of saturated chlorine weighs 12.8 gm. at 0° C. (32° F.) and 3.65 atmospheres pressure or 39.0 pounds gage pressure.

Density, Liquid Chlorine

1 liter weighs 1468 gm. at 0° C. (32° F.) and 3.65 atmosphere pressure or 39.0 pounds gage pressure—Temperature-Density Relation of Liquid Chlorine.

Flammability

Chlorine, gaseous or liquid, is non-explosive and non-flammable. Gaseous chlorine will support the combustion of certain compounds.

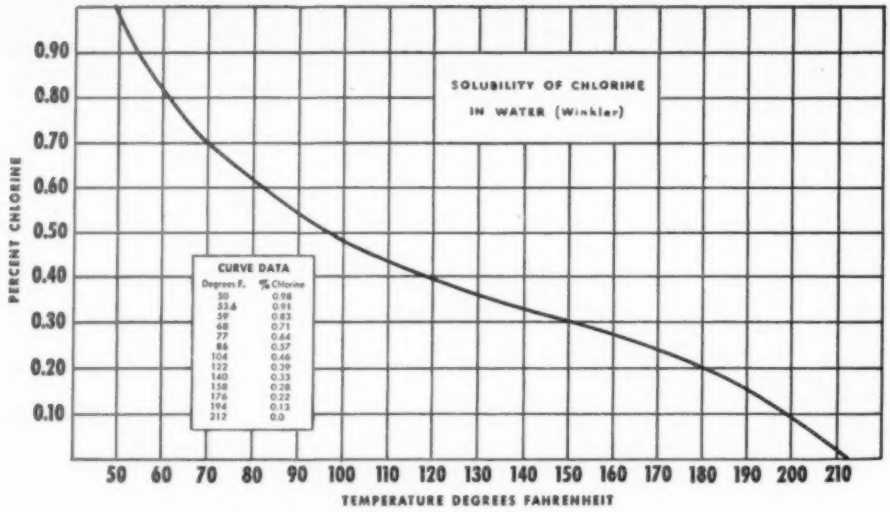


Fig. 10—Solubility of Chlorine in Water

Latent Heat of Vaporization

68.8 calories per gram at —34.05° C., or 123.8 B.t.u. per pound at —29.3° F. The heat units required to evaporate a unit weight of liquid chlorine.

Liquid-Gas Volume Relation

1 volume of liquid chlorine is equivalent to 456.8 volumes of gaseous chlorine at 0° C. (32° F.) and 1 atmosphere pressure. 1 pound of liquid chlorine is equivalent to 4.98 cu. ft. of gaseous chlorine at 0° C. (32° F.) and 1 atmosphere pressure.

Melting Point

—100.98° C. (—149.76° F.). The temperature, under atmospheric pressure, at which the solid melts or the liquid solidifies. Alternate term is freezing point.

Odor

Chlorine has a characteristic penetrating and irritating odor. (See Table A.)

Reactivity

Chlorine has a very strong chemical affinity for other substances. It will react with almost all the elements and with many inorganic and organic compounds, usually with the simultaneous evolution of heat.

Solubility, Gaseous Chlorine

The volume of chlorine gas, in terms of 0° C. (32° F.) and 1 atmosphere pressure, which can be dissolved in water at a given temperature when the added vapor pressure of the gas and the solvent equals 1 atmosphere. Below 9.6° C. (49.3° F.) chlorine combines with water to form a solid hydrate, $Cl_2.8H_20$. See Fig. 10—Solubility of Chlorine in Water.

Specific Gravity, Gaseous Chlorine

2.49. The relative density, at 0° C. (32° F.) and 1 atmosphere pressure, compared with air as unity.

Specific Gravity, Liquid Chlorine

1.47. The relative density, at 0° C. (32° F.) and 3.65 atmospheres pressure, or 39.0 pounds gage pressure.

Specific Heat, Gaseous Chlorine

0.115 calorie per gram per °C. at 15° C., or 0.115 B.t.u. per pound per °F. at 59° F., at constant pressure. At constant volume the specific heat is 0.0849. The ratio of $Cp/Cv = 1.355$. The heat units required to raise the temperature of a unit weight of gaseous chlorine one degree.

Specific Heat, Liquid Chlorine

0.226 calorie per gram per °C. between 0° and 24° C., or 0.226 B.t.u. per pound per °F. between 32° and 75° F. The heat units required to raise the temperature of a unit weight of liquid chlorine one degree.

Vapor Pressure

The pressure above liquid chlorine when liquid and gas are in equilibrium. See Fig. 8—Temperature-Pressure Relation of Liquid Chlorine.

Volume, Gaseous Chlorine

1 pound occupies 4.98 cu. ft. at 0° C. (32° F.) and 1 atmosphere pressure (Ref. 4).

Volume, Liquid Chlorine

1 pound occupies 0.011 cu. ft. at 0° C. (32° F.) and 3.65 atmospheres pressure or 39.0 pounds gage pressure (Ref. 5).

Volume-Temperature Relation

The volume of liquid chlorine increases rapidly as its temperature increases. The I.C.C. Regulations limit the loading density of chlorine containers to provide gas space in a full chlorine container at room temperature. A full chlorine container becomes completely filled with liquid when the temperature of the liquid reaches about 62.4° C. (153.4° F.). See Fig. 9—Temperature-Volume Relation in Liquid Chlorine Containers.

Weight, Gaseous Chlorine

1 cu. ft. weighs 0.2006 pounds at 0° C. (32° F.) and 1 atmosphere pressure.

Weight, Liquid Chlorine

1 cu. ft. weighs 91.64 pounds at 0° C. (32° F.) and 3.65 atmospheres pressure or 39.0 pounds gage pressure.

Selected References

A complete list of references on chemical and physical constants and on chlorine is given in Section N., page 30ff of *The Chlorine Manual.*

Administrative Code of the City of New York. Chapter 19. Title A. Fire Department. Title C. Fire Prevention Code. As Amended to September 1, 1942. With Supplements. The Eagle Library, Inc., Eagle Building, Brooklyn, N. Y.

Am. Pub. Health Assn. and Am. Water Works Assn.
Standard Methods for the Examination of Water and Sewage. Am. Publ. Hl. Assn., New York (9th ed., 1946).

Am. Water Works Assn.
Chemical Hazards Committee Report on Chlorine. Jour. Am. Water Works Assn., 27:1225 (1935).

Am. Water Works Assn.
Manual of Water Quality and Treatment. Am. Water Works Assn., New York (1st ed., 1940).

Association of American Railroads. Code of Rules Governing the Condition of, and Repairs to, Freight and Passenger Cars in the Interchange of Traffic. Association of American Railroads, 59 East Van Buren St., Chicago 5, Ill.

Association of American Railroads. Specifications for Tank Cars. Issued by Association of American Railroads, 59 East Van Buren St., Chicago 5, Ill.

Faber, Harry A.
Contemporary Chlorination Practices. Jour. Am. Water Works Assn., 39:200 (1947).

Hedgepeth, L. L.
Handling Chlorine to Avoid Trouble. Jour. Am. Water Works Assn., 26:1602 (1934).

Hedgepeth, L. L.
Preparing and Packaging Liquid Chlorine and Allied Products. Jour. New Eng. Water Works Assn., 52:1 (1938).

Hedgepeth, L. L. and Riggs, W. S.
Liquid Chlorine—A Critical Review of Chlorine Specifications. Jour. Am. Water Works Assn., 30:1671 (1938).

Henderson, Y. and Haggard, H. W.
Noxious Gases and the Principles of Respiration Influencing Their Action. Reinhold Publishing Corp., New York (1943).

Interstate Commerce Commission Regulations for Transportation of Explosives and Other Dangerous Articles by Land and Water in Rail Freight, Express, and Baggage Services, and by Motor Vehicle (Highway), and Water, Including Specifications for Shipping Containers. Supt. of Documents, Washington, D. C.

Jones, A. T.
The Treatment of Casualties from Lung Irritant Gases with Particular Reference to the Use of Oxygen and Carbon Dioxide Mixture. Jour. Indus. Hyg. & Toxicology, 22:233 (1940).

National Safety Council.
Respiratory Protective Equipment. Safe Practices Pamphlet No. 64. National Safety Council, 20 North Wacker Dr., Chicago, Ill.

Quinn, R. J. and Vincent, G. P.
Liquid Chlorine—Methods That Reduce Risk in Handling. National Safety News, 51:22 (1945).

Schuber, J. and Phelps, M. W.
Chlorine Safety Measures. Tech. Assn. Pulp and Paper Indus., Tech. Assn. Papers, Series 22, No. 1:436 (1939).

U. S. Department of Labor, Division of Labor Standards.
Chlorine. Controlling Chemical Hazards, Series No. 2 (1945).

MICHIGAN SEWAGE ASSN. FEATURES INDUSTRIAL WASTES ON PROGRAM

Resulting in Record Attendance at Jackson Meeting

WITHOUT much doubt the drawing power of a full day devoted to industrial wastes on the two and one-half day program of the 22nd Annual Meeting of the Michigan Sewage Works Association accounted for the record making attendance of 278 at the 1947 meeting held in Jackson, Mich., May 14-16.

Presidents

(Retiring)
R. A. Greene
Chemist and Act'g Supt.
Treatment Wks.
Jackson, Mich.

(Incoming)
T. J. Powers
Supt.
Waste Treatment
Dow Chemical Co.
Midland, Mich.

A second cause for the record attendance can be stated to have been the generally excellent and interesting technical program dealing with sewage topics; also the interest taken in the meeting by the Jackson authorities, including Mayor Kearney and City Manager Elliott, and the issuance of the completed program well in advance and the accompanying letter from John M. Hepler, Chief Engr. of the Mich. State Dept. of Health. Such a combination never fails to ring the bell in drawing excellent attendances at such meetings. And it was a well satisfied attendance, too, because the boys all went home thoroughly satisfied that they had been well repaid for having come.

The Michigan program represented some hard work, and we wish to compliment the new Secretary-Treasurer, Don M. Pierce, and his associates on the job done in developing such a program. It was thought that not less than 70 of the 278 attending were attracted by the two sessions devoted to Industrial Waste Problems, and 50 of this number registered as employees or representatives of industry.

After a brief address, highly complimentary of the management and operation of Jackson's treatment works by City Manager Clarence H. Elliott, the program got under way.

City Mg'r. & No. 1 Host
C. H. Elliott
Jackson's City Manager

Sup't. of The Day
*Dean List**
High School Senior
Jackson

*(*Member of Class in American Government appointed by Mayor Kearney as "Supt. of Sewage Works for the Day.")*

Maintenance of Sewage Treatment Works

(A Panel; C. T. Mudgett, Leading)

The first topic dealt with was that of **"Waterproofing Structures,"** discussed by R. D. Thayer, contractor of Detroit, who pointed out that temperature changes are more responsible for disintegration of masonry structures than is generally appreciated. Moisture penetration and freezing and thawing is not as generally responsible as ordinarily considered.

In repairing spalling, Mr. Thayer favors metallic admixtures in the mortar. In the line of surface coatings he recommends a prime penetrating coating and then an oil type of plastic coating (non-asphaltic). He said that great promise is held for the new inorganic silicones such as are being produced by the Dow-Corning Corp. At present he is trying these interesting compounds which come in the form of liquids as thin as water and ranging up to the consistency of heavy grease.

Nat'l. Director*
W. F. Shephard
Engineer
State Dept. Hlth.
Lansing, Mich.
*(*Federation Bd.)*

Sec'y.-Treas.
Don M. Pierce
Engineer
State Dept. Hlth.
Lansing, Mich.
(Newly Elected)

"The Maintenance of Equipment" was discussed by M. A. Groen, Supt. of Treatment Works, Dearborn, Mich., who commented on the greater importance today of good mechanics in the modern treatment plants than chemists or engineers. Dearborn conducts regular instruction classes in maintenance of equipment, as well as in sewer maintenance and correct functioning of treatment processes and devices. In discussing lubrication, Mr. Groen advised operators to have a reliable oil company survey their plants and give a schedule of oils and greases for the individual units of equipment; however, keeping in mind the desirability of reducing the variety of lubricants to a minimum. In the Dearborn plant they had standardized on a Socony Vac.

Vice-Pres.
A. T. Kunze
Engr. in Chg.
Water & Sewage
Wayne Co.
Detroit

Director
C. T. Mudgett
Supt.
Sewage Wks.
Muskegon, Mich.

Director
Paul Stegeman
Supt.
Water & Sewage Works
Midland, Mich.

Director
Earnest Boyce
Professor
San. Engineering
Univ. of Mich.
Ann Arbor

Oil of "EEE" grade for most applications, and "Viscol" grease where grease is required. Mr. Groen closed by describing the results of plant flooding at Dearborn and the fact that all 115 motors and pumps were reconditioned by plant personnel alone. This one experience was ample evidence of the value of the maintenance instruction classes.

E. F. Eldridge, of Mich. State College, recommended to the members purchase of the U. S. Army Maintenance Manual for Sewage Works, T.M.-5-566, procurable from the Govt. Printing Office in Washington for 50 cents per copy. This Manual, which cost the Army a goodly sum, was produced during the recent war as a guide to sewage works operators at Army Posts.

"Plant Records" was the subject assigned N. G. Damoose, Director of Public Service, Battle Creek, Mich., and former Supt. of Treatment Works. Mr. Damoose said that in his present position he appreciated more than ever the value of dependable and informative plant records. Especially important is the daily log which may serve to combat nuisance suits, and explain later happenings in the plant process. Mr. Damoose, in listing the several reasons for keeping plant records as full as is permissible, emphasized the development of informative Annual Reports with explanations understandable to the general public. He then displayed the Battle Creek Monthly Report Forms and remarked that there should be some movement started in the direction of evolving standardized report forms for various types of plants.

Mr. Damoose spoke of the value of utilization of digester gas for power and the marketing of sludge for fertilizers as two operations which had public appeal and constituted the best sort of publicity for the sewage treatment plant. The public can understand Battle Creek's reports when the gas engine operation is reported in equivalent miles of travel had the engine been in an automobile. Battle Creek sells prepared sludge fortified with vitamin B_1 in 50 lb. bags locally. It costs $8.60 per ton to dry, shred and pack and it retails at 1 cent per pound ($20.00 per ton) at the plant or at 60 cents per bag from retailers in town, there being 22 firms handling all that the plant can produce. Recently they had shipped some prepared sludge in bulk (carlots) at $14.00 per ton delivered, the profit being only $6.00 per ton and not attractive. The most effective use of sludge locally (and the most profitable) had been the distribution in liquid form direct from digesters at 1 cent per gal. Realizing that the liquor is high in ammonia compounds, the wet sludge runs 3.2 to 3.5 per cent available nitrogen. To it is added vitamin B_1. Concerning the question of health hazard, he had examined digested liquid sludge for 15 years and had yet to find a pathogenic organism, so has no fears in advocating its general use.

Carbide Lime Slurry for Sludge Conditioning

On this topic there were two reports from the Wayne County (Detroit Area) plants and the large plant of Detroit proper. Both had found the lime bearing residue from carbide used in producing acetylene gas of practical value in conditioning sludge for vacuum filtration and more economical and more easily used than lime previously employed.

Co-Chairmen of Entertainment

(For the Ass'n)
R. B. Jackson
Plant Engr.
Sewage Wks.
Jackson

(For the Mfrs.)
"Walt" E. Smith
Distr. Mgr.
Wallace & Tiernan
Detroit

(The "Club Room" was a success; the two dinners and entertainment enjoyable.)

Reciting Wayne County experiences, **Harold M. Leonhard,** Chief Chemist, reported use of this slurry at the central dewatering plant serving eight individual plants from which sludge is transported by tank trucks to the central plant. These same trucks are used for hauling the carbide slurry.

The carbide slurry (2½ lbs. CaO per gal avg.) is purchased for $1.00 per ton for the dry content. Haulage adds $1.42 per ton. The slurry storage tank of 10,000 gal. capacity, pumps and feed control box cost $2,165 installed and was soon paid for from the savings of about $5,000 per year net. The 18 month average cost for lime requirement is 9.7c per 100 lbs. of dry sludge solids dewatered as against the earlier cost of 17.6c per 100 lbs. with lime. With the slurry there has been a slightly less ferric chloride requirement, namely, 3.75 vs. 4.07 lbs. per 100 of dry solids handled.

In plant use the slurry is thinned to run 2 lbs. of CaO per gal., is kept agitated by pump recirculation and fed from an orifice box of constant head. The scheme requires less maintenance and handling than does the old lime scheme. An interesting discovery was that a 2 inch recirculation line gave trouble from choking. It was replaced with a ¾ inch line equipped for flushing at high velocity.

Citing Detroit's experiences with carbide sludge slurry, **Fred H. Burley,** Engr. in Charge of Sewage Treatment at Detroit, said that they could afford to have this slurry hauled 7 miles to plant on contract at a net of one-half the cost of pebble lime compared on CaO content of each material. The overall chemical cost at Detroit is $1.31 to $1.89 per 100 lbs. of sludge dewatered on a dry solids basis. The slurry is stored in two 12,000 gal. tanks originally used for lime storage and is kept agitated by air as the most effective method tried. For feeding a bucket elevator type feeder is used, orifice feeding having been unsatisfactory. For transfer of slurry from tank truck dump pit to storage tanks a Chicago Scru-Peller Pump has proved ideal. Mr. Burley thought any plant operator with a carbide slurry pond within a 7 mile haul would be wise and happier if converting from the use of lime to the more easily handled slurry, even at no overall saving in costs.

Hepler on Porto Rican Sanitation

At the close of the Annual Dinner, **John M. Hepler,** Chief Engr. of the Michigan Dept. of Health, gave a talk on Porto Rican Sanitation, illustrated with Kodachrome slides. One of the interesting disclosures was the fact that Porto Rico has established a Federal Aqueduct and Sewerage Authority which is making excellent progress in providing modern water supply and sewage treatment facilities for the communities of Porto Rico. In the interest of saving time and expense, this Authority has made good use of the package type sewage treatment plant developed in the U. S., there being about 17 such plants already installed. It is regretted that space limits preclude the full coverage of Mr. Hepler's interesting review.

Programmers

Walter Drury
S. D. & McN. Engrs.
Ann Arbor

Geo. Liddle
City Manager
Muskegon

Milton Adams
Exec. Secy.
Strm. C'ntr'l Com.
Lansing

Fred H. Burley
Engr. in Chg.
Sewage Works
Detroit

E. F. Eldridge
Eng. Expt. Sta.
State College
East Lansing

C. L. Palmer
San. Engr.
City Engrs. Dept.
Detroit

Leonard Howell
City Manager
Port Huron

The Club Room

Before and following the two dinners the manufacturers' representatives held "open house" in the club room in a pleasing manner on all four occasions. It has been the observation of this reporter that wherever the Club Room Committee is effectively organized in advance of meetings, as was the case at the Michigan meeting, this method of entertainment has been enjoyable, effective and popular. To W. E. Smith, F. W. DuBois and Harry Potts goes the credit for the success of the Michigan Club Room. And we should add, also to R. B. Jackson, of Jackson, as Chairman of the Local Entertainment Committee, who also effectively served as M. C. at the two dinners and "general manager" of the meeting as a whole.

Operation and Control of Sludge Digestion Facilities

(A Round Table; C. P. Witcher, Leader)

"Digester Loadings" was introduced by Mr. Witcher and discussed by **W. F. Shephard,** Chief of the Sewerage Div. of the Mich. Dept. of Health, who stated that some standardization on terminology and units used in digester loadings is badly needed. Mr. Shephard prefers the unit of "Lbs. volatile solids/cu. ft. capacity/day" as the most definite of the units in use. In a study of Michigan plants with 8 to 35 lbs. vol. solids/cu. ft./day it is the state's conclusion that the design minimum should be somewhere between 25 and 35 lbs./cu. ft./day. In these times of garbage digestion and handling of organic industrial wastes the old per capita capacity unit is outmoded. For digestion of primary sludge the limits may be 30 to 35 lbs., whereas for a mixture of primary and activated sludge 25 to 30 lbs. seems to be the limit. In the well operated plant of Jackson, Mich. (primary and activated sludge), the loading of 32 lbs. shows some deterioration of supernatant in Feb. and March. Mr. Shephard believes that the inert matter in sludges should be considered also, simply because of the space it occupies in the digesters and represents a reduction in overall digester volume. This inert matter is not alone solids but consists also of the water entering the digesters with the sludge.

Programmers

N. G. Damoose
Director of Public Services
Battle Creek

Michael Groen
Supt. Sewage Treatment
Dearborn

Leonard Hillis
Supt. Sewage Treatment
Caro, Mich.

"Stage vs. Single Unit Digestion" was introduced by Mr. Witcher, who believes that single stage digestion is neither completely satisfactory nor practical. The minimum should be a two stage digestion. H. J. Spader of The Dorr Co. was called upon for comment. He spoke on the economy of single stage digestion for the smaller plants with digesters up to 40 ft. diameter. In the larger plants and particularly where industrial wastes are handled, two stage digestion is indicated on all scores. He spoke on the value of some form of agitation and thorough mixing of raw sludge and seeding sludge in the first stage.

L. H. Enslow said that he had thought that stage digestion had become generally accepted as superior, the question being how many stages. In Los Angeles County studies of large scale operation had indicated 3 stages to be the minimum and 4 stages to be preferable. At one time this particular plant employed as many as 7 stages but 3 of the 7 had since been considered as of little added worth. For mixing recirculation in the primary stage seems highly important in releasing gas and speeding digestion.

R. A. Greene, Chief Chemist, Jackson, Mich., said that they had found but little advantage when

H. A. Trebler
Chem. Engr.
Nat'l Dairy Prod.
Baltimore, Md.

"Russ" Grinnell
Chief Operator
Birmingham

H. J. Spaeder
Sales Engr.
The Dorr Co.
Chicago

K. W. Cosens
Engineering Prof.
State College
East Lansing

R. A. Anderson
Supt.
Sewage Works
Muskegon Hgts.

M. W. Reynolds
Supt.
Water & Sewage
Durand

A. E. Griffin
Devel. Engr.
W. & T. Co.
Newark, N. J.

operating with three stage digestion as compared to parallel operation of the three digesters.

C. P. Witcher, presenting Ann Arbor experiences in digesting primary and activated sludge, said they held to the limit of sludge import to digesters on any one day equivalent to 5 per cent of the volume of the digester, thus giving a theoretical 20 day digestion period. He prefers sludge recirculation to other methods of mixing but finds that recirculation gives a gas higher in carbon dioxide and hydrogen sulphide. As to sludge heating, Mr. Witcher thinks preheating before entering the digester is preferable to other methods. If heating coils are to be in the digester, the vertical coil is preferable because it can be removed and worked on without desludging the tank.

As to the handling of supernatant from the digesters, Mr. Witcher warns against its return to the head of the plant. The introduction of supernatant to the aeration units direct is preferable by far.

"Dewatering Qualities of Sludges" was next taken up with the question, "Which digestion process yields the most easily dewatering sludge?"

R. A. Greene (Jackson) said that no sludge dewaters any more effectively than Imhoff tank sludge. Otherwise, a digestion temperature of 75 to 80° F. gives the best dewatering sludge. At 90° F. the digestion is speedier but the sludge dewaters much more slowly. Higher temperatures are worse still. In short, the bottleneck in practical plant operation may be the time element in dewatering if digestion is speeded up too much by heating.

L. H. Enslow pointed out that the amount of gas left in the sludge was the important consideration in dewatering. A gas filled sludge floats and allows the water to seep through the sand bed. This stage is the most important in the process of dewatering. If the gas has been taken out by agitation and high temperature, then it becomes necessary to add gas artificially through the addition of a coagulant which clots the sludge but more importantly liberates carbon dioxide gas, which floats the sludge as a blanket on the water, which then seeps through the bed unobstructed by a sludge matte. Almost any acid will produce flotation, including chlorine gas, but the coagulant such as alum or an iron salt has the added advantage of forming sludge curds or flocs and liberates water from the colloidal solids. Because of the value of gas in sludge it has often been observed that a completely digested sludge may dewater less effectively than an under-digested sludge. The worst of all though is what is known as a sour sludge from a plant with a seriously overloaded digester or one that has remained chilled through the winter and digestion has been almost at a standstill.

Concerning stage digestion, Mr. Enslow noted that for economy's sake the smaller plants were constructed to provide single stage digestion only. He thought it a deplorable economy just the same and wondered why it had not been expedient and practical to construct circular digesters with a center compartment as the first stage chamber and use the annular space as the second stage chamber. Heat input would be applied to the central compartment and the insulating effects of the surrounding layer of sludge would be of value in conserving heat. In addition, the sludge in the second stage compartment or annular ring could be made to travel the full way around the tank, thus providing in effect a multistage process and productive of a high grade supernatant and a thick sludge at the far end of the travel. Little or no scum should be found in the outlet zone if observation of long narrow digesters had been any indication of what to expect from the long travel around the annular outside ring of the digester. The central (primary) compartment could be constructed of metal or a thin masonry wall since there would be no pressure differential on either side of the center cylinder.

Engineering Planning of Sewers and Treatment Works

In his discussion of "Engineering Planning of Sewage Collective Systems and Treatment Works," **Professor Earnest Boyce,** Univ. of Michigan, said that the design of sewer systems or treatment plants without adequate pre-design knowledge of maximum conditions or even average conditions should not be permitted to continue. The all important factor in proper sewer and plant design has been shown to be maximum conditions (loadings) and not the average. By the same token many industrial wastes can be treated in municipal plants if such plants are designed on the basis of handling peak loads rather than average loads, largely because average loads are *not* average but in reality represent an averaging of slugs of waste or peaks of domestic flows.

The same reasoning applies to the establishment of standards for plant effluents. Average quality of effluent is not a sufficient standard. The requirement should specify some maximum total weight of pollution from a treatment plant in some specific period. In other words, two plants may be producing effluent of the same quality, whereas the one plant may be 10 times the size of the other and therefore actually contributing 10 times the pollution to the stream. This comparison and argument for total weight limitations on pollution applies even more in the case of industrial wastes than in the case of domestic sewage.

J. R. Rumsey
San. Engr.
Mich. Stream Control Comm.
Lansing

R. D. Craun
Supt.
Treatment Wks.
Rochester, Mich.

W. M. Wallace
Supt.
Water Purif. & Sewage Trtm't
Detroit

Frank R. Cheek
San. Engr.
Sewage Wks.
Dearborn, Mich.

F. D. Young
Sales Engr.
Johns-Manville Transite Div.
Cleveland, O.

Wm. J. Garan
Supt. of Sewerage
Ludington, Mich.

A. J. Fisher
Devel. Engr.
San. Div.
The Dorr Co.
New York

Indust. Waste Programmers

A. J. Steffen, Research Engr., Wilson & Co., Chicago
John Dobson, Devel. Engr., W.& T. Co., Newark, N. J.
Phil. Morgan, Field Engr., Nat'l Council, Kalamazoo
T. F. Wisniewski, Engineer, Wis. Dept. Hlth., Madison, Wis.
C. W. Hathway, Metallurgist, Gen'l Motors Corp., Detroit

Mr. Boyce said that in this direction plant effluent lagoons to smooth out variations in plant effluent quality might well prove the overall most economical solution of the problem of smoothing out plant effluent deficiencies, thus relieving the stream of performing as the effluent lagoon, as too often is the case at present.

Walter Drury, Consulting Engr. of Ann Arbor, in discussing Prof. Boyce's paper, pointed out that engineers would always argue as to how far to go in providing treatment for storm flows from combined sewers which in many instances will never be separated into sanitary and storm sewers. He cited hypothetical illustrations of the variable results from bypassing varying percentages of storm flows and the impracticability of refinement as long as streams vary in volume of flow as they do. As to industrial wastes, in his opinion these wastes should as a rule be treated at the point of their origin and not in municipal plants.

Financing of Sewer Systems and Treatment Plants

The first of two papers on this important topic was presented by **Leonard Hillis,** City Manager for Port Huron, Mich., who explained the Michigan law permitting the establishment of sewer districts within a municipality for the purpose of constructing and financing sewerage improvements separately from the financing of other municipal functions and thus having no relation to the limits of indebtedness of a municipality. In the Michigan Legislature at present is a Revenue Bond Act which will permit financing sewerage improvements by issue of revenue bonds.

Mr. Hillis told of the requirements of the State that Port Huron construct sewage treatment works involving a $822,000 sewer interceptor project which will be paid for to the extent of $664,000 by the city proper and the balance to be financed through assessment. The entire project of providing three treatment plants is to be financed from revenue bonds, $1,600,000 of which had already been sold in March at an interest rate of only 1.347 per cent. A sewer service charge amounting to 80 per cent of the water bills is being instituted.

Session Chairmen

J. E. Cooper, Supervisor, Water & Wastes, Ford Motor Co., Dearborn (Chm. Ind. Wastes Sessions)
C. P. Witcher, Supt., Sew. Treatment Works, Ann Arbor (Chm. Sludge Digestion Session)

George Liddle, City Manager for Muskegon, told how in 1934 he had consolidated the water and sewage departments of Muskegon Heights and lacking revenue bonds in those times had decided to finance operating costs of the sewerage system and treatment plant on a utility basis; he placed the sewer service charge at 50 per cent of the water bill and it stuck.

Now, in Muskegon water and sewerage projects planned are to cost $750,000 each. These are to be financed through issue of revenue bonds to be supported through water sales and a sewer service charge. However, the water bill and sewer charge will be billed separately, although this does not appeal as the correct method to Mr. Liddle, who believes that it is a case of water in and water out and therefore the billing should be consolidated on a single statement.

Experience With a Small Activated Sludge Plant

Experiences with "The Maintenance and Operation of a Small Activated Sludge Plant" were recited by an industrious and conscientious plant operator, Leonard Hillis, Supt. of Sewage Treatment at Caro State Hospital, Caro, Mich.

Mr. Hillis began by saying that after 5 years of experience in operating this small activated sludge plant a novice operator cannot learn plant operation from what others tell him.

The small mechanical aerator plant of Caro has a tough job handling institutional sewage composed of 40 per cent laundry waste. The chief difficulty has been bulky sludge and leaf troubles—i.e., leaves blowing into the mechanical aerator. Also the primary tanks get septic in summer, and although the effluent is pre-aerated, the dissolved oxygen drops to 1 ppm. in the mechanical aerator during peak load periods and to zero in the final tank. Based on experience, 1600 to 1800 parts of solids in the mixed liquor is required to handle peak loadings. Attempts to adjust the mechanical aerator mechanism to take care of peak loads had met with only partial success from a practical standpoint.

Mr. Hillis said that the return of supernatant liquor always upsets the activation process, although the supernatant is of pretty fair quality. The digester seems to perform very well even though the scum layer is 5 to 6 ft. in depth. The pH of the digester is O.K. and the

Warren Dubay, Chemist Treatment Plant, Pontiac, Mich. and Stanley Bower, Supt., Treatment Plant, Ypsilanti, Mich.

Paul Wolterink, Supvr. Waste Trtm't and Jack Nieboer, Operator, Waste Trtm't Plant, Meade Johnson Co., Zealand, Mich.

Ben H. Barton, Supt., Treatment Wks., Findlay, Ohio and Floyd S. Browne, Consulting Engr., Marion, Ohio

sludge dewaters well. The digester temperature is maintained at 85 to 90° F.

Chlorine had been tried in efforts to control bulking of sludge. The method had been fairly successful but it had been observed that the chlorination seemed to release grease or fats which float and have to be skimmed from the clarifiers. In this connection he spoke of the importance of good housekeeping in operating a small plant as well as a large plant. Otherwise, the plant appearance becomes two strikes against the operator even though the plant may be producing a good effluent. Mr. Hillis closed with a pat on the back for the comminutor, which is a great boon to the small plant with limited operating personnel.

R. A. Greene, (Jackson, Mich.) was highly complimentary of the thought and untiring efforts which Mr. Hillis had put into his job. He pointed out the inherent difficulties of the activated sludge process and did not believe it a practical process for small plants subject to such strong sewage and shock loadings as experienced at institutions, hospitals, and the like. Also, the cost of effective supervision, maintenance and operation of small activated sludge plants was something to consider. More importantly and even with careful supervision at high cost, the activated process in such plants produces erratic results in comparison with the less spectacular but dependable "workhorse" in sewage treatment—the trickling filter.

Walter Drury, Ann Arbor Consulting Engr., expressed the opinion that even small treatment plants should be designed with duplicate units operating in parallel, thus producing greater flexibility in operation and ease in proper maintenance.

Industrial Waste Sessions

(Program Chairman: J. E. Cooper, Ford Motor Co.)

The two sessions on industrial wastes and their disposal were opened with some "Introductory Remarks" by E. F. Eldridge, Research Associate, Eng. Expt. Sta. of Michigan State College, East Lansing, Mich.

Mr. Eldridge outlined a three point attack advocated in solving industrial waste problems:

(1) The testing period for evaluating the quantity and qualities of the various wastes from a given plant.

(2) The period of instituting recovery and utilization methods for reducing such wastes within the plant.

(3) The period of developing proper treatment of the final wastes which cannot be further reduced economically by re-use, recovery, changes in plant processes, or improved design, use, etc., of plant equipment.

He pointed out the great importance of steps (1) and (2) to industry from the standpoint of potential economy in waste reduction and pollution alleviation. Consulting firms operating in the industrial waste field need have on their staff someone familiar with industrial processes. In addition, the basis for charging for services will need to be different from that employed in municipal plant design and supervision.

"The State's Attitude on Industrial Pollution" was reviewed by Milton P. Adams, Exec. Engr. and Secy., Mich. Stream Pollution Comm., Lansing, Mich.

Mr. Adams, commenting on the strong convictions of the new Governor of Michigan (Mr. Sigler) that stream pollution must be abated, reviewed the findings of a special committee appointed by the Governor to study the status of pollution and report with recommendations. The report recommends that the State should take the lead in securing pollution abatement by industry; that no municipality be permitted to discharge less than settled sewage into waterways; that the legislature give municipalities relief in bonding restrictions where sewage treatment is ordered; that enforcement be applied to industry as to municipalities; that a new "Water Resources Commission" be established for the specific purpose of effecting stream pollution control, and such Commission be adequately staffed and financed.

Mr. Adams pointed out that in Michigan there are 755 separate existing problems of pollution, about half of which are considered as being in violation of existing law. Many orders have been issued with many more to follow. A number of municipalities have undertaken to assume responsibility for industrial wastes, but the results have not been happy ones in most instances because the wastes are adversely affecting sewage treatment, with the result that treatment is deficient for both sewage and wastes.

Concerning the matter of developing stream standards and minimum standards for effluents, Mr. Adams considers the waiting for such standards to be impracticable and too delaying. Efforts should be made promptly to affect such pollution reduction as is practicable for the present and let the standards develop in the future.

As to municipal financing, the legality of Revenue Bonds for sewerage improvements makes the financing possible without excluding debt limits. Sewer Service Charges will pay operating and maintenance costs.

On the whole, Mr. Adams said that the "State's Attitude" could be summed up under three headings:

(1) Cooperation from polluters must be more than has yet been shown in general.

(2) Existing and future treatment plants must be given better operation and maintenance by better qualified personnel.

(3) More court actions appear warranted in order to attain results and not delaying tactics.

"An Industry Initiates a Waste Disposal Program" by J. E. Cooper, Supervisor, Water and Wastes Laboratories, Ford Motor Co., Dearborn, Mich.

Mr. Cooper described the new Water and Waste Laboratories recently established by the Ford Motor Co. to handle problems in water supply, waste utilization and treatment and allied problems. The personnel of the laboratory consists at present of the supervisor, a secretary and five technicians, who are studying water treatment and industrial waste problems. At present specific attention is being given to reducing oily wastes, the longer use of plating baths and treatment of ammonia still wastes. Mr. Cooper described the experimental water filter and waste treatment plant at Dearborn and the very completely equipped laboratories. He also pointed out the fact that laboratories had the assistance and guidance of the new Chemical Engineering Research Dept. and the Chemical and Metallurgical Dept. to depend upon wherever needed in Ford problems.

Mr. Cooper said that the policy of the new laboratories was to first save and reuse every wasted material possible, especially oils and greases, which represented such a vast monetary loss to the company. Many other internal savings were to be studied ahead of waste treatment, since a treatment plant designed today might well be obsolete almost before its completion. He explained a method of making flow

Nicholas Herda
Utilities Supt.
Kaiser-Frazer
Willow Run,
Mich.

Clark C. Smith
Maint. Supt.
W. & S. Systems
of Wayne Co.
Detroit

*E. D. Cattell**
Supt. of
Distribution
Jackson,
Mich.

Wm. C. Gibson
Engr.
Sewerage Div.
Mich. Dept. Hlth.
Lansing

A. R. Cook
Engr.
Revere
Copper Co.
Detroit

Allan Kronbach
Supt.
Sewage Trtm't
Monroe,
Mich.

Harlan Dodge
Cons. Engr.
Francis
Engineers
Saginaw

**Chairman, Michigan Section, American Water Works Assn.*

measurements of giant proportions through the use of sulphuric acid rapidly mixed and determining the sulphate content of the flow turbidimetrically. This scheme had proved the only practical means of determining some flows.

"Determination of the Degree and Type of Treatment Required for an Industrial Waste" by Phillip F. Morgan, Engineer in Charge of Kalamazoo Project, the National Council for Stream Improvement of the Pulp and Paperboard Industries, Kalamazoo, Mich.

Mr. Morgan's highly interesting paper reveals the exactness with which studies have been made of the effects of pollution by 13 pulp, paper and paperboard plants located on the Kalamazoo River. This study, representing an ideal project, was conducted as a cooperative undertaking by the National Council for Stream Improvement (Pulp and and Paperboard Industries) and the Michigan Stream Control Commission. The reason for the study was that of determining the type and extent of treatment required for the wastes involved. A 34 mile stretch of the river was covered in the study which employed 13 sampling points and a complete map of the stretch made from aerial photographs.

One extremely interesting phase of the study was the ability to obtain river conditions during a two week period of summer when the mills on the river were shut down and dissolved oxygen, oxygen demand, suspended solids and pH values at the 13 stations could be compared with and without the paper plant wastes entering. Concurrently the wastes from the several mills were measured, sampled and studied to determine their rates of oxygen demand in 5 gal. carboys.

Michigan's Dean of Operators*

Thomas J. Doyle
Supt. Sewage Works
Pontiac, Mich.

*(*Mr. Doyle, a veteran operator with a highly credible background, operated the first U. S. plant of size to employ rotary distributors for trickling filters. Because of the heavy overload, Pontiac's filters eventually functioned as high-rate filters, although not recognized as such at the time. When taking into account the overload handled and the unattractive appearance of the effluent, Pontiac's filters were considered at the time to be surprisingly effective in respect to pounds of BOD removed without attendant nitrification.)*

It is thought that this Kalamazoo project represents the most thorough and intensive pollution study ever made of a stretch of stream, together with concurrent studies of the wastes for the purpose of establishing the extent of treatment required for the wastes of an industry. We regret that space available does not permit of a more detailed account of the survey, study and research which proceeded simultaneously as a joint undertaking of a cooperative industrial organization and a State agency.

"Treatment of Cyanide Wastes by Chlorination" by John G. Dobson, Development Engr., Wallace & Tiernan Co., Newark, N. J.

Mr. Dobson, stating that up to the present there are only three plants employing alkaline chlorination to destroy cyanides in electroplating wastes, explained the reactions involved in the chlorination process and the simple equipment required. These plants are located at Johnsville, Pa., Meadeville, Pa., and at one unidentified location. [Ed. Note: The Johnsville plant has been described by Freil & Weist in the March 1945 issue of *Water Works and Sewerage*. The Meadeville plant is the subject of an article by Prof. Geo. E. Barnes, scheduled for an early issue of this magazine.]

Mr. Dobson, with slides, described the arrangement of automatic chlorinators and lime or caustic soda feeders to maintain a pH of 8.5 or higher for the purpose of converting cyanides to cyanates, which are only 1/1000th as toxic as the cyanides. To produce cyanates, each part of cyanide (CN) requires 2.73 parts of chlorine and 3.08 parts of caustic soda (NaOH). If it be desired to carry the oxidation to completion, in order to destroy even the cyanates by converting them to

Norman A. Miller
Operator Trenton Plant
Wayne Co. Sewage Wks.
and
Harold M. Leonhard
Chief Chemist
Wayne Co. Sew. Wks.
Wyandotte, Mich.

C. A. Habermehl
Supervising Chemist
and
L. M. Reading
Senior Operator
Sew. Treatment Wks.
Detroit. Mich.

Milton P. Adams, Ex. Sec.
Stream Control Comm.
Lansing
Bernard Moll, San. Engr.
In Chg. Sew. Treatm't
Grand Rapids
Jim Rumsey, San. Engr.
Stream Control Comm.

Murray M. Smith
Engr. & Supt. Pub. Wks.
Grosse Point Farms
and
G. E. Flower
Field Engr.
Automatic Controls Co.
St. Paul, Minn.

L. F. Oeming, San. Engr.
Stream Control Comm.
Lansing
and
Harry G. Potts, Dis. Mgr.
Penna Salt Mfg. Co.
Wyandotte

carbon dioxide and nitrogen, the required ratio of chlorine to cyanide is 6.8 to 1 and caustic soda 4.6 to 1. To speed the reaction, 8.7 ppm. chlorine to each ppm. of cyanide is employed, the conversion being 90 per cent complete in 10 minutes and 100 per cent complete in 30 minutes. In all cases a positive residual chlorine is required, and since the plating wastes contain other chlorine consuming materials, the overall chlorine requirement will be variably higher than the theoretical values given herewith. The control resides in the simple maintenance of residual chlorine and a pH at 8.5 or above in the treated waste. Even if there is a residual of cyanates, these compounds hydrolyze in the stream into ammonia and carbon dioxide.

Dr. A. S. Hazzard, Director of the Institute of Fisheries Research, Mich. Dept. of Conservation, reported on studies involving the effects of chlorinated cyanide wastes on young fish. In a chlorinated sample of wastes originally containing 25,000 parts of cyanide (CN), less than 1 ppm. of unconverted cyanide could be found. This treated waste killed none of the standard test fish after as much as 96 hours of exposure. An investigation by G. M. Ridenour of the Univ. of Michigan had revealed also that this chlorinated waste had no deleterious effects on activated sludge or on sludge digestion. Therefore, chlorinated cyanide wastes may be disposed of through a municipal sewer system with no ill effects.

"Municipal Regulations for the Control of Sewer Usage by Industry" by C. L. Palmer, Sr. Assoc. Engr., City Engineer's Office, Detroit.

Mr. Palmer reported that Detroit is now developing a new Sewer Ordinance which will embrace standards and specifications covering what is permissible in discharges to the city's sewers. Some of these limiting requirements are: (1) temperature, 32 to 150° F.; (2) pH of 5 to 10; (3) suspended solids not over 1000 ppm.; (4) grease or oil, 100 ppm.; (5) antiseptic substances, 100 ppm.

Mr. Palmer then explained Detroit's Sewer Control program in which a 4-man Sewer Safety Crew is continuously surveying sewers and turning up remarkable information as to contributions, repairs needed, "lost" manholes, and the like. During 1946 many violations had been discovered, principally wastes from oil refineries and acid wastes, all but four having been corrected. These four violators had now been taken into court.

C. W. Hathway, Engineer, General Motors Corp., commented that Detroit's Sewer Standards and Regulations seem to be fair and reasonably applied.

"The Use of Lagoons and Nitrate Treatment for Disposal of Cannery Wastes" by T. F. Wisniewski, Sr. Asst. Engr., Wis. State Dept. of Health, Madison, Wis.

Mr. Wisniewski reported the most practical and economical method yet developed for disposing of the seasonal cannery wastes in Wisconsin to be lagoon storage, supplemented by treatment with nitrate of soda to preclude odor nuisance.

The most effective lagoons are 3 to 5 ft. deep only, with a holding capacity 25 per cent greater than the volume of the season's complete waste output. For odor control, mechanical screening of the wastes (40 mesh screens) is of great importance. The sodium nitrate is added as a solution (2 lb./gal.), 200 lbs. being added to the day's waste from each 1000 can pack. The nitrate costs $36.00 per ton delivered. The cost of lagoon operation and treatment per case of cans has averaged 45 cents as compared to 85 cents for chemical precipitation and $1.45 for biological treatment. The construction cost of a lagoon to handle 10 m.g. of wastes having a 15 acre area averages about $8,150. Maintenance cost (labor) and interest is $795 per year for a 10 m.g. lagoon and amounts to roughly 2 cents per case of canned vegetables.

Mr. Wisniewski stated that with nitrate treatment and a lagoon containing 25 per cent of its capacity in digested waste to begin the season on a B.O.D. reduction of 80 per cent takes place in the first 30 days of storage. Effective lagooning is productive of an effluent of 45 ppm. 5 day B.O.D. at the outlet. In this thorough paper no questions have been left unanswered by Mr. Wisniewski.

Business Meeting and New Officers

In the Business Meeting it was reported that the membership increase of 39 so far during the year constituted a record, and at least 15 additional new members seems assured within the month.

Reporting for the Educational Committee (N. G. Damoose, Chm.), C. A. Habermehl directed attention to the arrangement for a 6 weeks' course for plant operators at Michigan State College, the courses to be held so that attendants will not have to take the full six weeks in any one year unless they are so situated that they can do so.

J. R. Rumsey called attention to the more than 100 new sewage treatment plants to be constructed in Michigan and the 335 industrial waste violations to be prosecuted immediately. He wanted to know where operators for these plants were to come from.

The following officers were chosen for the ensuing year:

President—T. J. Powers, Supt. Waste Disposal Div., Dow Co., Midland.

Vice-Pres.—A. T. Kunze, Supt. Wayne Co. Water & Sewage Systems, Wyandotte.

Secy.-Treas.—Don M. Pierce, Asst. Engr., State Dept. of Health, Lansing.

Director—M. A. Groen, Supt. Sewage Treatment Wks. Dearborn.

Director—Earnest Boyce, Prof., San. Engineering, Univ. of Mich.

The National Director and member of the Board of Control of the Sewage Works Federation is W. F. Shephard, long-time Secretary of the Michigan Association, who reminded members of the 1948 Federation Convention to be held in Detroit Oct. 17-21, 1948, at the Hotel Statler.

It is regretted that because of space limitations the following papers presented at the Jackson meeting cannot be reported:

"Chlorination of Sewage" by O. E. McGuire of the State Dept. of Health, Escanaba, Mich.

"Reduction of Pollution by Milk Plant Wastes" by A. J. Steffen, Research and Technical Dept., Wilson & Co., Chicago.

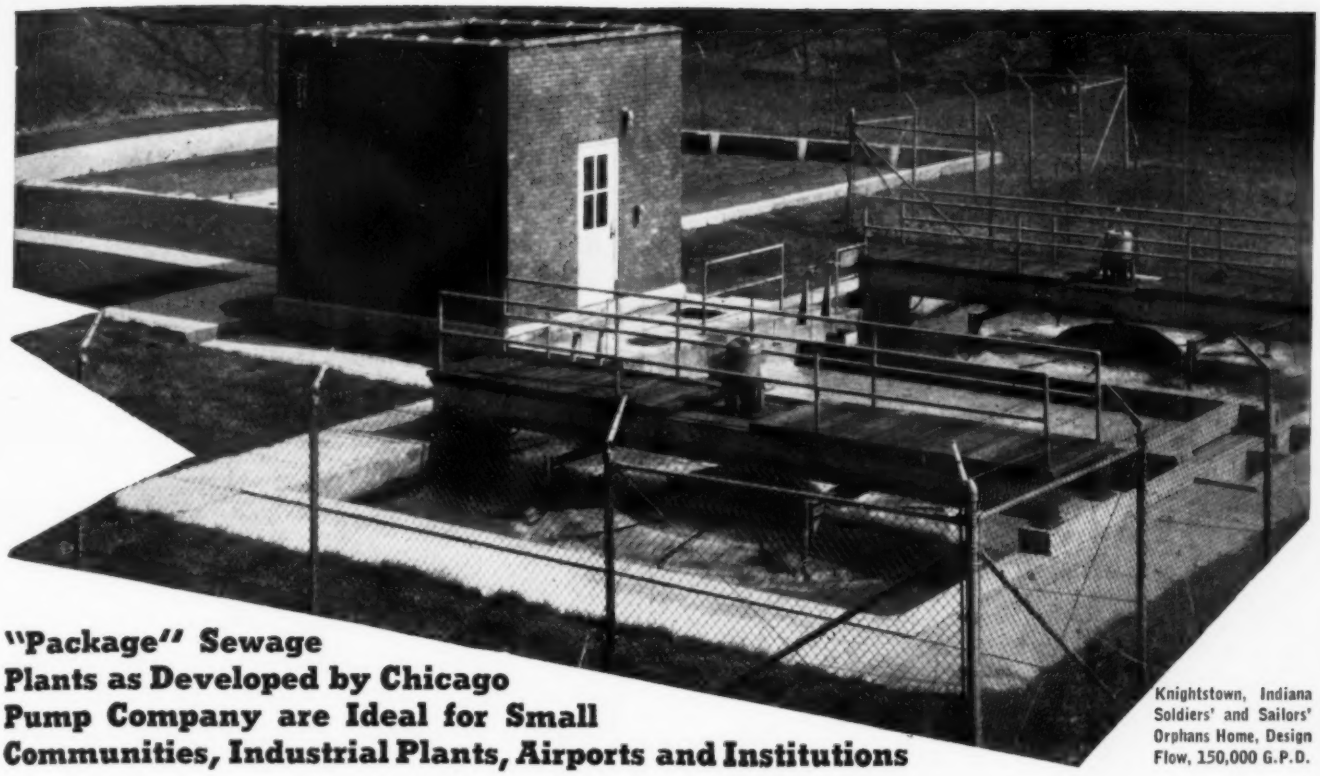
Do You Serve This Brand of Water?

Two Mountaineers who had never seen water come out of a faucet went to town and prepared to spend the night at a hotel. They were awed by the wonders of the city and just before retiring drew two glasses of water. As one tried a couple of sips, a power failure occurred, throwing the room into total darkness.

First Mountaineer — "Hev you drunk yore's yet?"

Second Mountaineer—"Nope."

First Mountaineer—"Well, don't touch it. I took one swig and I've gone blind as a bat."



"Package" Sewage Plants as Developed by Chicago Pump Company are Ideal for Small Communities, Industrial Plants, Airports and Institutions

Knightstown, Indiana Soldiers' and Sailors' Orphans Home, Design Flow, 150,000 G.P.D.

Because-

They require a minimum of operating supervision, produce a sparkling clear effluent, are free from flies, foul odors and unsightly appearance. Can be located near dwellings.

Initial cost of "Package" plants is low and they are inexpensive to operate.

Local Operators without previous sewage treatment experience successfully operate these plants. Former farmers, salesmen, coal-miners, truck-drivers are operating existing plants and performing other municipal duties.

Operator training service by Chicago Operating Sanitary Engineers is provided with each plant. Ingenious automatic features of Chicago "Package" plants simplify operation and assure successful performance.

Aeration and clarification are performed in a single tank with positive, automatic sludge control. One sludge setting covers a wide range of sewage flows and strengths.

Since 1934 over 100 plants have been installed and are successfully operating.

Properly designed, these units can handle industrial, cannery and other wastes as well as the usual community sewage.

The "Package" plant was specifically developed for small populations and can be engineered to meet requirements. Complete literature available.

See display at the Water and Sewage Works Convention, San Francisco, July 21st-25th

CHICAGO PUMP COMPANY

SEWAGE EQUIPMENT DIVISION

2349 WOLFRAM STREET — **CHICAGO 18, ILLINOIS**

Flush-Kleen, Scru-Peller, Plunger, Horizontal and Vertical Non-Clogs, Water Seal Pumping Units, Samplers.

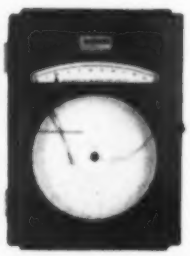
Swing Diffusers, Stationary Diffusers, Mechanical Aerators, Combination Aerator-Clarifiers, Comminutors.

PLANT-WIDE INFORMATION AND CONTROL...

at your fingertips

Builders Chronoflo Telemeters centralize all plant data on one control panel. No longer is it necessary to operate a water works plant by guesswork or to travel long distances reading meters and gauges at remote installations or reservoirs. Builders Chronoflo Telemeters instantly bring complete and accurate readings of level, flow, pressure, temperature, gate position, weight, etc., to the central operating building. They operate over a simple two-wire private or leased circuit for any distance, from a few feet to many miles, and are widely used for automatic proportioning control of chemical feeding. All Builders Chronoflo Instruments are simple and dependable; their attractive, uniform design enhances the appearance of any water works.

For Bulletin 320B, address Builders-Providence, Inc., (Division of Builders Iron Foundry), 10 Codding Street, Providence 1, R. I.



BUILDERS CHRONOFLO INSTRUMENT

BUILDERS PRODUCTS

Venturi, Propeloflo and Orifice Meters • Type M and Flo-Watch Instruments • Venturi Filter Controllers and Gauges • Master Controllers • Kennison Nozzles • Chronoflo Telemeters • Conveyoflo Meters • Wheeler Filter Bottoms • Filter Operating Tables

BUILDERS PROVIDENCE *Instruments*

MEETINGS SCHEDULED

July 21-25—SAN FRANCISCO, CALIF. (Auditorium)
American Water Works Association 1947 Conference. Executive-Secretary, Harry E. Jordan, 500 Fifth Ave., New York 18, N. Y.

July 22-24—SAN FRANCISCO, CALIF. (Auditorium)
Federation of Sewage Works Associations. (20th Annual Meeting.) Executive-Secretary, W. H. Wisely, 325 Illinois Bldg., Champaign, Ill.

(Meetings and Exhibits in the Auditorium.) Application blanks for hotel accommodations may be obtained from the respective Association Headquarters.

Aug. 13—CARIBOU, ME.
Maine Water Utilities Assn. Sec'y, Earle A. Tarr, Winthrop, Me.

Aug. 25-27—STATE COLLEGE, PA. (Nittany Lion Inn)
Pennsylvania Sewage Works Assn. Sec'y-Treas., Bernard S. Bush, Kirby Health Center, Wilkes-Barre, Pa.

Aug. 27-29—STATE COLLEGE, PA. (Nittany Lion Inn)
Pennsylvania Water Works Operators' Assn. Sec'y, I. M. Glace, 1001 Front Street, Harrisburg, Pa.

Sept. 4-5—PLATTSBURG, N. Y. (Hotel Champlain)
New York Section, A.W.W.A. Secretary, R. K. Blanchard, 50 West 50th St., New York, N. Y.

Sept. 16-19—BOSTON, MASS. (Statler Hotel)
New England Water Works Assn. Sec'y, Jos. C. Knox, 609 Statler Bldg., Boston, Mass.

Sept. 17-19—ATLANTA, GA. (Ga. School of Technology)
Annual Water & Sewage School. Sec'y, Van P. Enloe, Rt. 5, Box 363, Atlanta, Ga.

Sept. 18-20—BAY CITY, MICH.
Michigan Section A.W.W.A. Sec'y, R. J. Faust, State Dept. of Health, Lansing, Mich.

Sept. 22-24—LOUISVILLE, KY. (Brown Hotel)
Kentucky-Tennessee Section A.W.W.A. Sec'y, R. P. Farrell, 420 6th Ave., N., Nashville 3, Tenn.

Sept. 30-Oct. 1—COLUMBUS, OHIO (Deshler-Wallick Hotel)
Ohio Section A.W.W.A. Sec'y-Treas., F. P. Fischer, 812 Perry Payne Bldg., Cleveland, Ohio.

Oct. 2-3—COLUMBUS, OHIO (Deshler-Wallick Hotel)
Ohio Conference on Sewage Treatment. Sec'y-Treas., L. B. Barnes, 441 S. Prospect St., Bowling Green, Ohio.

Oct. 2-3—BLUEFIELD, W. VA. (Hotel West Virginian)
West Virginia Section A.W.W.A. Sec'y, J. B. Harrington, State Department of Health, Charleston, W. Va.

Oct. 8-10—ATLANTIC CITY, N. J. (Haddon Hall)
Pennsylvania Water Works Association. Sec'y-Treas., E. R. Hannum, 510 Telegraph Bldg., Harrisburg, Pa.

Oct. 6-8—NIAGARA FALLS, ONTARIO (General Brock Hotel)
Canadian Institute on Sewage & Sanitation. Sec'y-Treas., A. E. Berry, Ontario Department of Health, Toronto 8, Ont.

MEETINGS SCHEDULED

Oct. 6-10—ATLANTIC CITY, N. J. (Convention Hall)
American Public Health Association. (75th Annual Meeting.) Exec.-Sec'y., Reginald M. Atwater, M. D., 1790 Broadway, New York, N. Y.

Oct. 8—DOVER-FOXCROFT, ME.
Maine Water Utilities Assn. Sec'y, Earle A. Tarr, Winthrop, Me.

Oct. 9-11—CEDAR RAPIDS, IOWA (Hotel Montrose)
Iowa Section A.W.W.A. Sec'y-Treas., H. V. Pedersen, Municipal Bldg., Marshalltown, Iowa.
(Joint meeting with)
Iowa Sewage Works Assn. Sec'y-Treas., Robert D. Mott, Iowa City, Iowa.

Oct. 13-15—AMARILLO, TEXAS (Hotel Herring)
Southwest Section A.W.W.A. Sec'y-Treas., L. A. Jackson, Robinson Memorial Auditorium, Little Rock, Ark.

Oct. 16-17—OCEAN VIEW, VA. (Hotel Nansemond)
Virginia Industrial Wastes & Sewage Works Assn. (First Annual Conference). Sec'y-Treas., A. H. Paessler, 815 E. Franklin St., Richmond 19, Va.

Nov. 3-5—ATLANTA, GA. (Biltmore Hotel)
Southeastern Section A.W.W.A. Sec'y, W. T. Linton, State Board of Health, Wade Hampton Office Bldg., Columbus, S. C.

Nov. 6-8—ATLANTIC CITY, N. J. (Hotel Claridge)
New Jersey Section A.W.W.A. Sec'y-Treas., C. B. Tygert, Box 178, Newark, N. J.
(Joint meeting with)
South Jersey Assn. Water Supts. Sec'y, Walter Spencer, 2707 Bethel Ave., Merchantville, N. J.

Nov. 10-12—GREENSBORO, N. C. (Sedgfield Inn)
North Carolina Sewage Works Association. Sec'y-Treas., Geo. S. Moore, P.O. Box 125, Albemarle, N. C.

Nov. 12-14—PITTSBURGH, PA. (Hotel Wm. Penn)
Engineers' Society of Western Penna. (8th Annual Conference) Gen. Chairman, H. M. Olson, Wm. Penn Hotel, Pittsburgh, Pa.

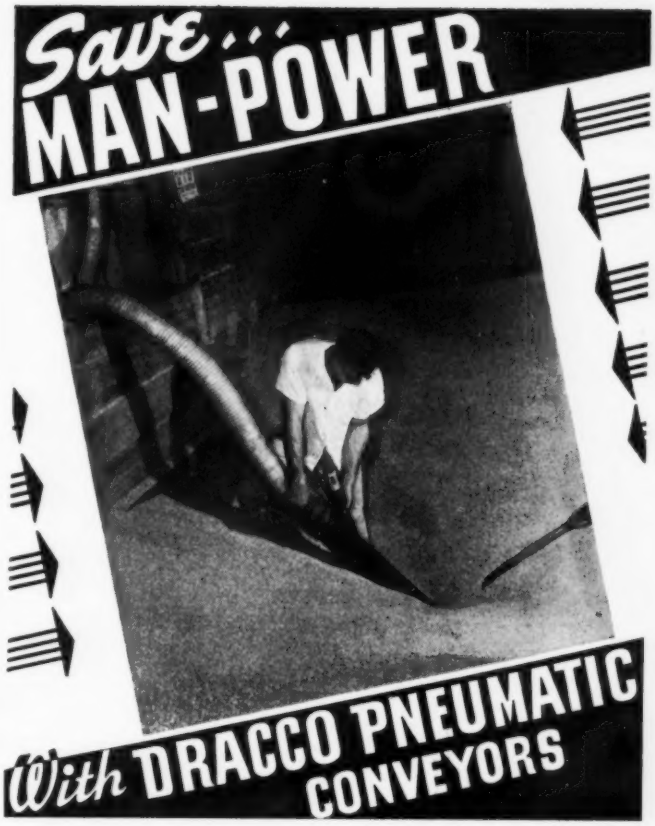
Nov. 17-18—ROANOKE, VA. (Hotel not selected)
Virginia Section A.W.W.A. Sec'y-Treas., W. H. Shewbridge, 708 State Office Bldg., Richmond, Va.

Nov. 19-21—WASHINGTON, D. C. (Hotel not selected)
Four States Section A.W.W.A. Sec'y-Treas., W. A. Welch, 748 Public Ledger Bldg., Philadelphia, Pa.

Nov. 20—BOSTON, MASS. (Statler Hotel)
New England Water Works Assn. Sec'y, Jos. C. Knox, 609 Statler Bldg., Boston, Mass.

Dec. 10—WINTHROP, ME.
Maine Water Utilities. Sec'y, Earle A. Tarr, Winthrop, Me.

Dec. 18—BOSTON, MASS. (Statler Hotel)
New England Water Works Assn. Sec'y, Jos. C. Knox, 609 Statler Bldg., Boston, Mass.



The following Chemicals are efficiently and economically handled by DRACCO Pneumatic Conveyors in Water Works and Sewage Treatment Plants located in all parts of the country. Alum, lime, soda ash, bauxite, ferrous sulphate, pebble lime, activated carbon, and ammonium sulphate.

A PARTIAL LIST OF *DRACCO* INSTALLATIONS

FRIDLEY FILTRATION PLANT.....Minneapolis, Minn.
DALECARLIA FILTRATION PLANT.....Washington, D. C.
MUNICIPAL WATER SOFTENING PLANT.....Sandusky, Ohio
MUNICIPAL WATER SOFTENING PLANT.....Ames, Iowa
LEMIEUX ISLAND FILTRATION PLANT.....Ottawa, Ontario
MAHONING VALLEY SANITARY DISTRICT.....Niles, Ohio
MUNICIPAL WATER PLANT.....Columbus, Ohio
MUNICIPAL WATER PLANT.....Peru, Ill.
U. S. GOVERNMENT FILTRATION PLANT..Ft. Leavenworth, Kans.
MUNICIPAL WATER PLANT.....Hamilton, Ohio
BACHMAN WATER PURIFICATION PLANT.....Dallas, Texas
MUNICIPAL WATER PLANT.....Richmond, Va.
MUNICIPAL WATER PLANT.....Springfield, Ill.
MINNEAPOLIS-SAINT PAUL SANITARY DISTRICT..St. Paul, Minn.
(Sewage Disposal Plant, 2 installations)
MUNICIPAL WATER PLANT (2 installations)....Milwaukee, Wis.
MUNICIPAL SEWAGE DISPOSAL PLANT...Oklahoma City ,Okla.
MUNICIPAL SEWAGE DISPOSAL PLANT.....Denver, Colorado
MUNICIPAL WATER PLANT.....Covington, Ky.
MUNICIPAL WATER PLANT.....Ann Arbor, Mich.
CLAYTON SEWAGE DISPOSAL PLANT.....Atlanta, Ga.
SEWAGE DISPOSAL PLANT (2 installations).....Cleveland, Ohio
MUNICIPAL WATER PLANT.....Benton Harbor, Mich.
MUNICIPAL WATER PLANT.....Warren, Ohio
MUNICIPAL SEWAGE DISPOSAL PLANT.....Detroit, Mich.
MUNICIPAL WATER PLANT.....Flint, Mich.
CITY OF TORONTO WATER WORKS PLANT.....Toronto, Ontario
WATER FILTRATION PLANT.....Ottawa, Kansas
EL RENO WATER TREATMENT PLANT.....El Reno, Oklahoma
CITY OF GRAND FORKS.....Grand Forks, North Dakota
MUNICIPAL SEWAGE PLANT.....Pittsburgh, Pennsylvania
WATER FILTRATION PLANT.....Wichita, Kansas
INDIANAPOLIS WATER CO.....Indianapolis, Ind.
WATER FILTRATION PLANT.....Appleton, Wis.
MUNICIPAL WATER PLANT.....Chillicothe, Ohio

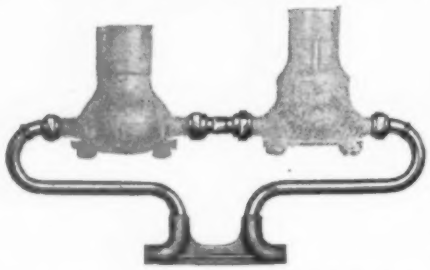
Write for Bulletin No. 526

DRACCO CORPORATION

4079 E. 116th St., Cleveland 5, O. ● New York Office, 130 W. 42nd St.

PNEUMATIC CONVEYORS • DUST COLLECTORS

AIDS IN MODERN METERING



The TANDEM RESETTER permits connecting two domestic meters in series without piping changes. These useful fittings are made in three types, for basement and outside meter settings.

To compare the performance of two meters in actual service, or to convince a skeptical customer that his meter is not too fast, it is frequently desirable to connect two meters in series. The simplest way to do this is to connect the bar of a TANDEM RESETTER into the position ordinarily occupied by the meter and then connect the meters into it.

Ford Meter Idlers are ideal to connect in place of meters when they are removed. They are all brass, with accurate threads, full gasket faces and wrench flats.

Meter Idlers are made in four sizes, for ⅝ , ⅝×¾", ¾" and 1" meters.

Meter adapters screw onto meters to build them out to the same thread size and length of larger meters so that they can be easily installed where larger meters have been. Many services are over-metered, and Meter Adapters on smaller meters offer a real economy in meters as well as better registration of the smaller flows.

* * *

Our catalog tells all about these Aids in Modern Metering. Your copy sent for the asking.

The

FORD METER BOX COMPANY, INC.,

WABASH, INDIANA

Here and There with Doc Symons

H.T.M.A.—And this month I'd like to remind you that this is *The* big number—Reference and Data—That Is!—And if you will look at the Foreword of that section, on page R-1, of this number, you will note that you should save the 1944, '45, and '46 issues as well in order to have a complete Reference and Data Library. As a matter of fact, there are some reference and data articles that have not been reprinted since 1941—But, in the back of this issue you will find a Consolidated Index for every article, chart, data table, etc., published in the *W. & S. W.* Ref. and Data issues since 1941.

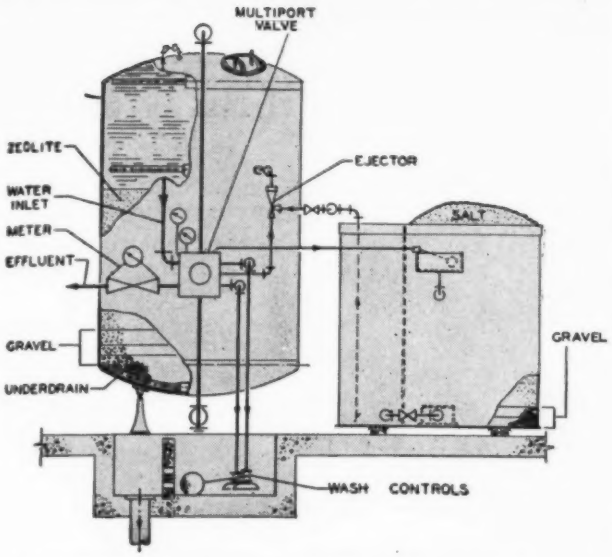
* * *

I Like Conventions Because—One meets such interesting people. F'r-instance, besides those pictured above, there were at the Md.-Del. meeting Mrs. Picton, Mrs. Fitzgerald, and the whole Stuart-Brumley family consisting of Grace (who calls me Sonny) Stuart, Mary-Libb Brumley and Mrs. Cecil Haney—and at the N. Y. S. S. W. A. - N.E.S.W.A. Joint meeting in Albany, there were Mrs. Herb Wagenhals, Mrs. Bill Edwards, Mrs. Fred Gibbs, Mrs. Stu Coburn, Edith (Mrs. "So") Dappert, Mrs. Tom Camp, Mrs. Larry Peck, Mrs. "Shorty" Germond, and Ruth (Smoke) Clement — and — Oh yes, their husbands.

* * *

Small World No. 4. One day in May, I picked up a copy of Philadelphia Quartz' *P's and Q's* (free adv.) and read about a mining engineer named H. P. Ehrlinger, Pres. of the Lead Carbonate Mines of Silverton, Colo., who has been improving gold recoveries by adding five cents worth of Metso silicate to a ton of ore. Surely there could be but one H. P. Ehrlinger, so I wrote him a letter and sure enough he turned out to be Hank Ehrlinger, one of my room

Why LIQUON SODIUM ZEOLITE WATER SOFTENER is ideal for many municipalities



A LIQUON Sodium Zeolite Water Softener is frequently the most advantageous method of softening hard water for households and industries, and has the following advantages as compared to other processes such as lime soda:

- Usually occupies much less space, due to its efficient design and the use of LIQUONEX CR, the modern high-capacity non-siliceous resin type of zeolite.
- Easier and simpler to operate, by means of an efficient single multiport valve which controls all operations with one lever.
- The treated water is stable and does not tend to after-react, even when the raw water varies in composition.
- Chemical costs less when non-carbonate hardness is high.
- Handling of chemical is much less troublesome.
- Forms no precipitates or sludge to cause disposal problems.
- Does not add any objectionable excess of reagent to the water.
- Can be operated under pressure and avoids re-pumping.

LIQUON equipment designs and process recommendations are based on 30 years of experience in specializing on water-conditioning problems. Write for Bulletin 5 describing LIQUON Zeolite Water Softeners, and for advice, without obligation, on any water-treatment problem.

LIQUID CONDITIONING CORPORATION

114 East Price Street, Linden, N. J.
Engineering Service Representatives in Principal Cities

Liquon

EVERY PROCESS . . EVERY TYPE OF EQUIPMENT for conditioning of water and other liquids

Dependable! Rugged!

VALVES HYDRANTS

M & H Flap Valve

VALVES: A.W.W.A. type iron body, bronze mounted with double-disc parallel seat or solid wedge type. Non-rising stem, outside screw and yoke, or with sliding stem and lever. Also furnished hydraulically operated. Square bottom type operates in any position. All rugged and dependable, made of best material with highest quality workmanship. *Hydraulically Operated:* For remote control of operation and for quicker, easier opening or closing. Can be supplied in any of the standard sizes of M & H A.W.W.A. gate valves, either high or low pressure.

HYDRANTS: Standard A.W.W.A. type approved by Underwriters and Factory Mutuals. Dry top, revolving head, easy to lubricate. High efficiency because barrel diameter not reduced and there are no working parts or obstructions in waterway. SPECIAL TRAFFIC MODEL is designed to yield at ground line under impact, repair being simply renewal of breakable bolts and breakable coupling on stem.

M & H Shear Gate

Write for Catalog No. 34

M & H PRODUCTS INCLUDE

FIRE HYDRANTS	SHEAR GATES
GATE VALVES	MUD VALVES
TAPPING VALVES	VALVE BOXES
WALL CASTINGS	FLAP VALVES
SPECIAL CASTINGS	SLUDGE SHOES
TAPPING SLEEVES	FLANGE AND FLARE FITTINGS
CHECK VALVES	FLANGED FITTINGS
FLOOR STANDS	B & S FITTINGS
EXTENSION STEMS	CUTTING-IN TEES

M & H VALVE AND FITTINGS COMPANY

ANNISTON, ALABAMA

mates at the University of Wisconsin almost a quarter of a century ago.—Long time, no see!

* * *

L. E. Wickersham who recently gave me a wonderful story which I mixed up a bit, also gave me this story about a water works operator who included in his accounts an item for $50 for Roman Candles and $20 for five tons of ice. The two had no connection. The former were to scare away the martins and the ice perhaps was a bit of public relations.

A local swimming pool wanted to replace the warm water in the pool with cool fresh water but the water supply was dwindling and the operator didn't want to waste any water, so he sent five tons of ice to cool the pool. It worked, too. I don't know what the office manager of that water utility thought of these purchases but you'll have to admit that the ice was an unusual bit of public relations.

* * *

That was a few days ago!—When Fred (W & T) Merkle introduced me to his wife ("Kokomo" Bill Birch's charming daughter), Fred said, "This is 'Doc' Symons; I knew him when he was a youngster operating a filter plant." Then he stopped, looked at my bald pate and continued, "Er, Gives away my age doesn't it!"

* * *

If you're smart, why not say so!—My story about Art Welch in the April issue met with such pleasing response that I think I'll try another.

When Art was a student in college, he chanced one day to be in the library and noted a somewhat perplexed sweet young thing who apparently was having some difficulty finding what she wanted. Ever ready to do the good deed, Art stepped up and asked, "Are you looking for something?"

To which the S. Y. T. replied, "Yes, I'd like to find the encyclopedia."

And Art came back with, "What do you want to know."—That one sneaks up on you, doesn't it.

* * *

Good luck, Bill.—My erstwhile competitor, Wm. H. Lang, formerly Ass't. Editor of *Water Works Engineering* is now knee deep in Oil Refinery Waste Disposal Problems. As Sanitary Engineer for the Esso Engineering Dept. of the Standard Oil Development Co., "Bill" is heading up the division to study waste disposal for all of the Standard Oil of N. J. refineries. One of Jack Hinman's boys from State University of Iowa (not Iowa State), "Bill" has been with the Penna. Bur. of Parks, and was Chemist of the Newport News, Va., Water Works Commission before going to *W. W. E.*

* * *

Special Announcement!!!—What, Again?—And this one is for those hardy members of the N.Y.S.S.W.A. and the N.E.S.W.A. who sat through my speech at the luncheon of that joint meeting of those two associations—You'll be happy to know that after giving the talk on how to write a paper and how to give a speech I took my own advice and cut twelve minutes out of it. If I'm ever asked to give it again, that will give me five minutes to ad lib which I always seem to be doing, and still get me away from the microphone in 35 minutes.—Oh, sure, I took out all of the tired ancedotes at which you didn't at least smile broadly, and then I took out most of the serious advice at which you didn't smile at all. Besides getting a chance to try out that talk on you, I learned that it should be strictly an after dinner talk and should not be presented either before or after any technical paper.—Thanks for the help!

* * *

● There are no tricky kinks of design in the Buffalo that are hard to understand or that make assembly difficult. No experts are needed to make a replacement or repair. There are fewer parts and they are all accessible.

Fair metering is a matter of ethics and it's the neighborly thing to install meters so that small flows or large flows are recorded accurately. In a small community Buffalo made American or Niagara Water Meters are first choice.

Cities, too, find the simplicity and moderate cost of Buffalo Meters make them the best investment.

Write for information covering simple design, easy assembly and interchangeability of Buffalo Meter parts.

AMERICAN BRONZE CASE NIAGARA GALV. IRON CASE
WATER METERS
BUFFALO METER COMPANY
2909 MAIN STREET • BUFFALO 14, NEW YORK
Simplicity

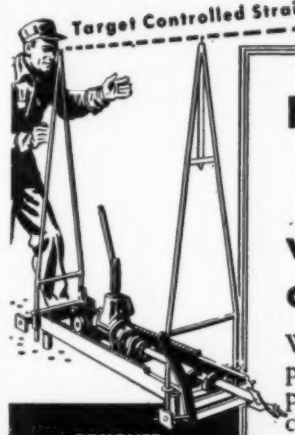
5 GOOD REASONS
for buying Blaw-Knox Grating
. . . COUNT 'EM!

1. STRONG electroforged construction for easy erection.
2. MAXIMUM OPEN AREA for light and air.
3. EASY TO MAINTAIN . . . paint reaches entire surface.
4. SELF-CLEANING, no sharp corners to clog.
5. SAFE footing at all times with twisted cross bar.

BLAW-KNOX DIVISION
of BLAW-KNOX CO.
2051 Farmers Bank Bldg.
Pittsburgh 22, Pa.

BLAW-KNOX ELECTROFORGED STEEL GRATING

Target Controlled Straight-Line Boring



DESIGNED ESPECIALLY FOR ONE MAN OPERATION

Operates on 90 lb. air pressure and a small stream of water

How to install PIPE with your air-compressor . . .

Why not utilize your air-compressor to do underground pipe installation? Much less costly than trenching; especially so because Hydrauger goes *under* pavement instead of *through* it! Anyone can operate the HYDRAUGER.

NEW
MODEL L-2

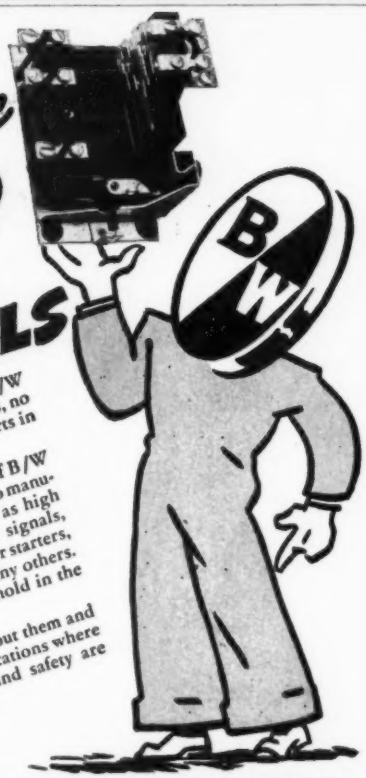
Bores 2" Dia. Reams 3½" and 4½" Dia. . . . makes 100' of clean, bored hole

HYDRAUGER*
*Reg. U. S. Pat. Off.
EARTH BORING TOOL

Write for CATALOG TODAY

HYDRAUGER CORPORATION, LTD.
116 New Montgomery St., San Francisco, Calif.

Floatless All Electric
LIQUID LEVEL CONTROLS



● All America knows about B/W Controls for liquids—no floats, no vacuum tubes—no moving parts in the liquid.

These controls are but part of B/W service to industry, for we also manufacture other controls, such as high and low water cut-offs and signals, low voltage control for motor starters, unit heater controls and many others. They are small enough to hold in the palm of your hand.

CATALOG 147 tells all about them and suggests many other applications where dependability, long life and safety are "musts."

B/W CONTROLLER CORPORATION

2206 E. Maple Road, Birmingham, Mich.

FIRST IN THE FLOATLESS CONTROL FIELD

---

3 *Money, Time and Labor Saving Features of*

UNIVERSAL CAST IRON PIPE

Laid with Only Wrenches →

No Caulking Materials →

No Gaskets. No Bell Holes to Dig. →

For water supply, fire protection systems, sewage disposal systems, industrial, and irrigation. Flexible.

Dept. C,
THE CENTRAL FOUNDRY COMPANY
386 FOURTH AVENUE, NEW YORK 16, N. Y.

Gentlemen: Send us information and catalog on UNIVERSAL CAST IRON PIPE.

NAME .....

STREET .....

CITY .....

Where Have I Read That Before Dept.—I want to thank J. W. Kellogg, Asst. Dir. of the N. Car. State Laboratory of Hygiene for his letter with the following malapropism: "A man who had patented a process for the treatment of sewage was explaining his process to the city fathers in a small mid-western town, when someone asked if he didn't use chlorine in the process. Drawing himself up to his full height he replied, 'Certainly not.' In my process the chemicals remove all these poisonous bacteria, but when you add chlorine the dead bodies of the bacteria are left there to petrify."

Mr. Kellogg says, "You may have seen it before." Would it hurt your feelings Mr. K., if I told you that I have seen it before in a column called, "Here and There with Doc Symons"—but I'm flattered that someone else saw it too. (I heard the story from Ferd (W & T) Fisher of Cleveland or Tommy Lathrop of the Ohio Dept. of Health at an Ohio meeting a couple of seasons ago.

Yep I'm flattered when some one sends me stuff I've written before, like the fellow who told me he had read somewhere that Harry Jordan and Pete Wisely, the respective secretaries of A.W.W.A. and F.S.W.A. were both born in the same Illinois town (Coulterville) and then this fellow added that he had recently read that Coulterville was getting a new water and sewer system. My helper went on to say that I should run an item in the column about those two fellows and the new water and sewer systems. Where do you think he had read those two stories?—Right—Here in this column—But don't get me wrong, I'm not complaining—It's flattering to know that my stuff is read.

* * *

"Looks like the water chemists don't rate too well with some people." So wrote J. C. Hill of the Standard Oil Co. (N. J.) at Baton Rouge, La., when he sent the following clipping from the "Letters to the Editors" of the New Orleans Times-Picayune.

City Water

New Orleans

Editor, The Times-Picayune:

Not only is the water "off color" but the taste is bad.

I am sure the chemists are honest about the water not being harmful: Perhaps we may say: "Too many chemists spoil the water," instead of "too many cooks spoil the broth."

Twenty years ago we had pure, tasty water. No outside agent spoiled it then.

MRS. RICHARD

Daily Bible Verse

Philippians 4:19

God shall supply

* * *

When one of my Hackensack, N. J. readers (one J. Van Atta) read in the May column that my blood pressure is 108, he took time out from selling sludge pumps to write that I must have meant my weight—Sir! Although I'll admit that early in 1942 the U. S. Navy turned me down simply and only because I was underweight, the fact remains that during this past winter I went on a diet to take off eight pounds. Did it, too!—Chum. Had to, you know—Was getting too big for my breeches!

* * *

Want to join a new club? I'm starting one to be known as the N.O.B.D.—"The Nimble Order of Bum Digits." All you need to join is a damaged or permanently injured finger (thumbs included). To date the charter members are B. A. Poole of the Indiana State Bd. of Health, W. D. Sheets of Worthington, Ohio, C. C. "Swede" Larson of Springfield, Ill., and yours truly.

THERE'S A ROYER MODEL
for every sewage plant

Your selling price for sewage sludge fertilizer is clear profit because preparation with a Royer Sludge Disintegrator costs less than burning or burying disposal costs. There's a model for your plant: portable or stationary; capacities from 1 to 12 cubic yards per hour; electric motor, gasoline engine, or belt-to-tractor drive. Norwalk, Ohio plant above handles 3 to 6 cubic yards per hour with their Royer Model NSB-2 . . . uses part of output as top dressing and fertilizer for lawns and flower beds on plant grounds and city parks. Two other models of same capacity are also shown. The Royer shreds, mixes, aerates, removes trash, discharges direct to bag or truck. Send for free Sewage Sludge Datalog—contains articles by agriculturists, plant superintendents . . describes all Royers.

ROYER

PIONEERS IN THE SALVAGE OF SEWAGE SLUDGE

ROYER FOUNDRY & MACHINE CO.
170 PRINGLE ST., KINGSTON, PA.

Write the latter before Sept. first for your charter membership card, in the N.O.B.D.

* * *

Know what Buffalo Bodie said when he read my June column?—"Holy Toledo"—That's all, just, "Holy Toledo."—V.T.Y. Doc.

[Overflow from the main section]

Leaking Water Main Repaired by Welding Without Discontinuing Water Service

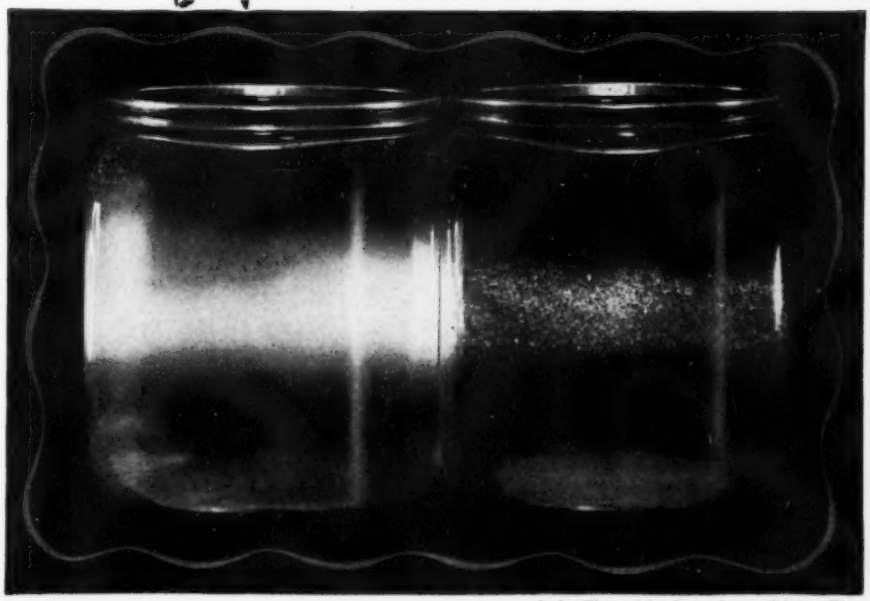
By Andy Miller

While working for the Jersey City Welding Co. of Jersey City, N. J., I was called out to repair a city water main in Bayonne, N. J., that was leaking badly. We were asked to repair the main, if possible, without having to shut off the water.

Patch Welding in a Wet Trench
(Photo, Courtesy Hobart Bros.)

To accomplish this job, without shutting the water off, I whittled a wooden plug to the size of the hole in the main and drove it in until it was tight. I then sawed the plug off even with the outside of the pipe. This plug stopped the leak sufficiently to enable us to weld a 6 in. diameter plate over the bad section, making a permanent repair

The accompanying photo shows the plate being welded to the main in a wet trench. Some steam, yes, but the job went well and the repair was a success without having to shut down this important water main.



Left: Floc with alum alone. Right: Floc with alum plus activated silica sol.

PIN-POINT? OR SNOW-STORM FLOC—the larger and heavier floc which enmeshes the suspended solids better, and settles more rapidly!

Get this increased floc size and improved clarity by using the activated silica sol coagulant aid made with sodium silicate. Besides clearer water, you can count also on longer filter runs and increased capacity.

Study now the benefits from the use of N-Sol Processes (activated silica sol) in your water supplies. For the correct results, send for fresh samples of N Brand with jar test directions.

Four ways of converting N Brand Sodium Silicate into useful coagulant silica sols to fit your conditions:

N-Sol-A*—N Brand reacted with ammonium sulfate. Used where chloramine sterilization is desired.

N-Sol-B—N Brand reacted with alum, Used with any sterilization procedure. (U. S. Pat. 2,310,009).

Baylis Sol—N Brand Silicate reacted with sulphuric acid. Used with any sterilization procedure. (U. S. Pat. 2,217,466).

N-Sol-D—N Brand reacted with sodium bicarbonate. Used with any sterilization procedure.

* Patent Applied For.

N-SOL PROCESSES FOR WATER COAGULATION

Developed and Patented by

Philadelphia Quartz Company

Available under license without charge • Philadelphia 6

Ten Packing "Don'ts" Worth Heeding

It is well known that "don'ts" are often more effective than "do's", so here are some suggestions and warnings arranged as "don'ts" that are based on many years of practical experience. They will be found useful in connection with the selection and installation of packings. To follow them may mean freedom from trouble that would occur when even the best obtainable packing is improperly installed.

1—DON'T fail to make clear what the packing is to pack. In other words, with what will the packing make contact?

2—DON'T guess at a size, diameter, width or height when ordering packings. Many failures have resulted from small errors in dimensions.

3—DON'T allow too little or too much clearance between follower plate and inside cup wall, or any metal parts behind any upright leather wall; 1/16 to 3/32 inch on each side, depending on size of packing, is usually recommended.

4—DON'T doctor packing lips with a pocket knife or file, or batter lip in installing. A rounded lip destroys the seal. Packings can be softened by soaking in warm water if necessary.

5—DON'T apply cup packings with flange too high for clearance at the head of the cylinder. Keep systems clean so sediment will not collect in cylinders and wear the packing.

6—DON'T apply cup packings to end of plunger which is badly worn; pressure will force the packing down into clearance between plunger and cylinder. Leather washers cut from old cup packings can be made to reline such equipment to proper dimensions.

7—DON'T apply "U" packings where plungers are worn without reinforcing under heel with leather cushion rings.

8—DON'T look for long service on scored plungers or in scored cylinders; resurface or reline such equipment to proper dimensions.

9—DON'T allow water to corrode cylinder walls, plungers or rods. Use an anti-rust agent that will prevent this and that will act as an effective lubricant.

10—DON'T squeeze hemp or fabric filled "U" packings in glands where such packings are to replace solid section compression packings; set glands up to point where "U" packings are free to function properly.

Contributed by W. F. Schaphorst, M.E., Newark, N. J.

TYPE A PUMPS FOR GENERAL and PROCESS SERVICES

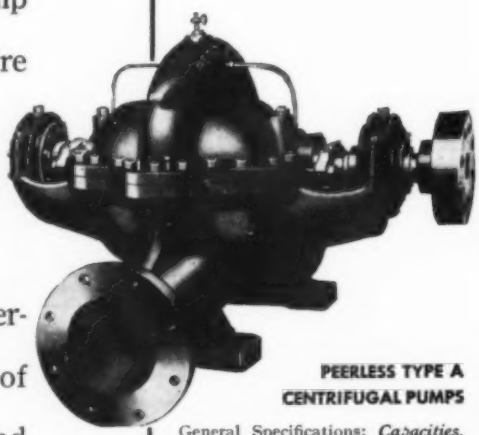
Capacities: 50 to 70,000 G.P.M.

PEERLESS Horizontal Centrifugal PUMPS

(Formerly Dayton-Dowd)

PEERLESS PUMPS

● The Peerless Type A pump is characteristic of the entire line of high quality, heavy duty horizontal centrifugal pumps, manufactured by Peerless to serve the diversified pumping demands of industry, municipalities and water works everywhere.



PEERLESS TYPE A CENTRIFUGAL PUMPS

General Specifications: *Capacities*, from 50 to 70,000 g.p.m.; *Heads*, 15 to 300 feet; *Sizes*, 2" to 42" discharge; *Drives*, electric and other types from 1 to 1000 h.p.; *Type*, single stage, double suction, split-case, ball bearing. REQUEST DESCRIPTIVE BULLETIN.

PLAN WITH PEERLESS

For all your pumping requirements, plan with Peerless. Peerless' comprehensive line of pumps includes Underwriters' approved Fire Pumps for plant fire protection, Boiler Feed and Pipe Line pumps and scores of other vertical and horizontal types producing capacities from 10 to 220,000 g.p.m.

PEERLESS PUMP DIVISION

FOOD MACHINERY CORPORATION

Factories: Canton 6, Ohio • Quincy, Ill. • Los Angeles 31, Calif.
District Offices: Canton 2, Ohio; Philadelphia: Suburban Square, Ardmore, Pennsylvania; Atlanta: Rutland Bldg., Decatur, Georgia.; Dallas 1, Texas; Los Angeles 31, California.

Quito Spending $4,000,000 for Water Supply

The City of Quito, Ecuador, S. A., has awarded a contract for new water supply system to Harold T. Smith, Water Supply Contractor, of that city. The new supply, costing $4,000,000 will be financed by a loan from the Export-Import Bank. The contract covers the design, construction, and administration for two years following completion of the work.

The Consulting Engineer who will make the preliminary studies to select the source of supply and design the system is Dr. George C. Bunker, well known to readers of this magazine and to the water works field in general for his long years of service in Panama and Venezuela. The contract for the new supply is similar to that made with the Frederick Snare Corp. for the new water supply for Guayaquil.

J. Barnhill Joins Metcalf & Eddy

John Barnhill, Chemist in the laboratories of the Illinois State Dept. of Health under the direction of C. W. Klassen, Chief Sanitary Engineer, has resigned his position there to become a chemist on the laboratory staff of Stuart Coburn, chemist of the firm of Metcalf & Eddy, consulting engineers in Boston.

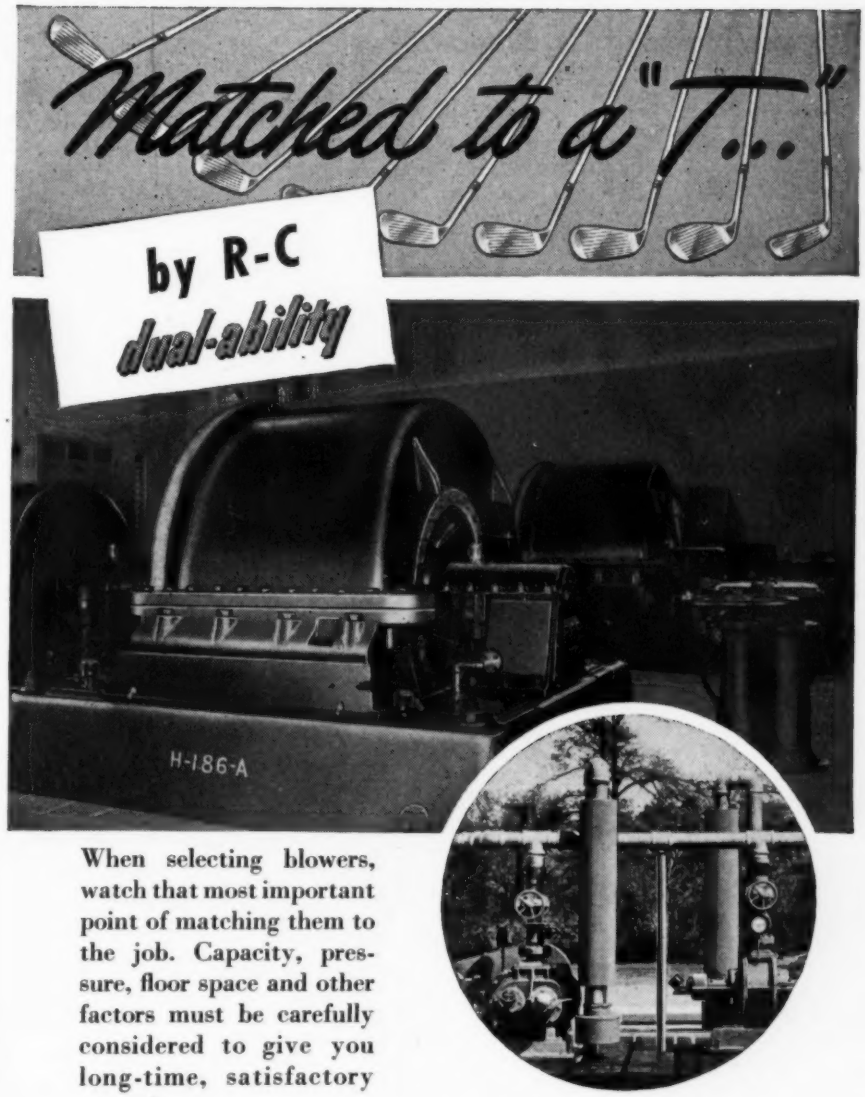
MANUFACTURERS' and EQUIPMENT NEWS

"D.M." Test for Algae Control

LaMotte Chemical Products Co. of Towson, Baltimore 4, Md., is offering the new "D. M." tube inversion rack for use with the "D. M." test for algae control as proposed by William D. Monie in *Water & Sewage Works*, vol. 93, page 173, 1946.

This simple procedure, designated as the "D. M." test, makes it possible to predetermine with exactness the amount of copper sulfate required to destroy and inhibit algae growth. Use of the test precludes waste of copper sulphate but insures that an ample supply is added in one operation.

Further information on this new piece of laboratory equipment may be obtained from LaMotte Chemical Products Co., Towson, Baltimore 4, Md.



When selecting blowers, watch that most important point of matching them to the job. Capacity, pressure, floor space and other factors must be carefully considered to give you long-time, satisfactory operation.

That's where R-C *dual-ability* goes to work for you. With small-to-large sizes and many styles of both Centrifugal and Rotary Positive designs, we are completely unbiased in our recommendations. For instance, the high-capacity Roots-Connersville Centrifugal Blowers (illustrated at top, above) best meet the needs of a large sewage plant in a metropolitan area. The small Rotary Positive units in the lower picture, equipped for outdoor operation, furnish ample air for a small, rural plant.

Similarly, your needs can be *matched to a "T"* with our small or large Centrifugal or Rotary Positive equipment. Send for new Bulletin 23-12-B10, illustrating a wide variety of interesting sewage plant installations, and proving that it pays to call on R-C *dual-ability* to solve blower problems.

ROOTS-CONNERSVILLE BLOWER CORPORATION
707 Mount Avenue, Connersville, Indiana

ROOTS-CONNERSVILLE
ROTARY CENTRIFUGAL
BLOWER BUILDERS · R-C · SINCE 1854
BLOWERS · EXHAUSTERS · BOOSTERS · LIQUID AND VACUUM PUMPS · METERS · INERT GAS GENERATORS

★ ★ ONE OF THE DRESSER INDUSTRIES ★ ★

Holyoke Machine Co. Enters Filter Field

The Holyoke Machine Co. of Holyoke, Mass., long known in the paper industry for its paper finishing machinery, cotton and paper calender rolls, etc., has announced its entrance into the gravity and pressure filter field.

When the Norwood Engineering Co. ceased operations last year, the Holyoke Machine Co. decided to take over tools, jigs, fixtures, patterns, etc., in order to service the paper companies using Norwood Engineering filters and equipment.

After surveying the general field of filter installations, the Holyoke Co. decided to expand their service and enter the general field of gravity and pressure filters. This filter department has been established under the direction of John W. Gaitenby, and the company will specialize in filters for municipalities, paper and textile trade, swimming pools, and soft drink bottlers.

The Holyoke Machine Co. is located in Holyoke, Mass.

HAYS MEMORANDUM HAYS

TO: A.W.W.A. Members

How about paying us a visit at Booth 56, A.W.W.A. Convention, San Francisco, July 21-25.

It's a good place to meet your friends, and you will want to see the new Hays "Duo-Stop"—the combination corporation stop and saddle — and the rest of the complete line of Hays Water Works Products.

We'll be looking for you.

Bert Howell, San Francisco, Calif.
Al Green, Seattle, Washington
John Adams, Los Angeles, Calif.
Pete Peterson, Southwest Territory
Les Buzzard, Erie, Pennsylvania
Jack Clemens, Erie, Pennsylvania

HAYS MANUFACTURING CO., ERIE, PA.

Hydraulic Pipeline Scraper

The Carver-Stimpson Pipe Cleaning Co. of Walters, Okla., is now marketing their Flex-O-Hydraulic Pipeline Scraper. This scraper, developed through fifteen years of pipe cleaning experience in the southwest, where all kinds of pipe scale and corrosion are encountered, is made of brass and spring steel, and is so constructed that all corrosion and scale removed by cutting knives is washed ahead of the scraper as the unit moves through the pipeline. This action prevents clogging of the tool by accumulation of debris.

The Flex-O-Hydraulic Pipeline Scraper operates entirely by hydraulic pressure, does not use any rods, cables, or pulling devices, may be obtained in 4, 6, 10, 12, and 14 in. sizes, will operate on 30 psi. and 100 gpm. volume of water in a 6 in. main, or pressure of half that in larger sizes.

The device, which will make a 90 deg. bend, is said to clean up to one mile per day in 6 in. mains, or more in larger sizes.

Further information on this new piece of equipment may be obtained from the Carver-Stimpson Pipe Cleaning Co., Walters, Okla.

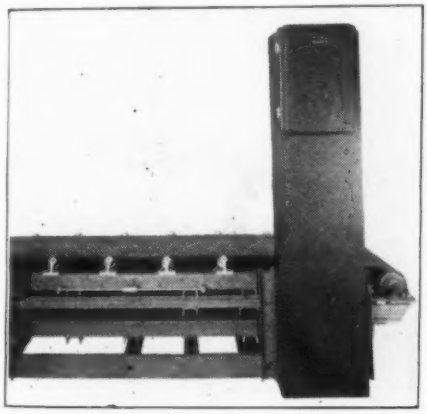
Payne Dean Has Demonstration Truck

Payne Dean & Co. of Madison, Conn., manufacturers of the Payne Dean Gate Operator and portable operators for floor stand and underground gates, as well as other equipment, has developed a demonstration truck on which is mounted a gate operator. This truck will be sent through the country to various sections where the company has a manufacturer's representative, and will be available for periods of several weeks in each area to demonstrate the operation of the gate operator to various water works superintendents and managers.

If you wish a demonstration of this gate operator, write to Payne Dean & Co., Madison, Conn.

New Continuous Weighing Device

Builders-Providence, Inc., is now offering a new development in the continuous weighing of dry materials on conveyor belts. Known as the Conveyoflo Meter, this unit utilizes diaphragms instead of the



usual knife-edge-beam principle for metering flow of dry materials by weight. Utilizing this diaphragm principle, a conveyor flow meter becomes a much simpler unit than former types of weighing devices of this general system.

Besides all types of dry materials such as coal, gravel, stone, powdered chemicals, etc., this Conveyoflo Meter may be used to weigh sewage sludge. A cyclometer type totalizer reads directly in any unit desired, and is non-cyclical in operation. Integration is automatically compensated for by variations in belt weight and for adherence of material to the belt through a system of return belt weighing.

Further information on this new Conveyoflo Meter may be obtained from Builders-Providence, Inc., Providence, R. I.

In One Sewage Job After Another Springfield Chooses MORRIS CENTRIFUGAL PUMPS

10 Morris Pumps in Five Different Stations

Station #1—1925

Three Morris Pumps, 24 inch suction and discharge, vertically driven by 100 HP electric motors. Each pump has capacity of 13,500 GPM against a head of 20 feet.

Station #2—1925

Two Morris self-contained, vertical, submerged pumps with a 5 inch suction and 4 inch discharge. Driven by 10 HP electric motors, they deliver 500 GPM against a total head of 40 feet.

Station #3—1935

Two Morris Pumps, 6 inch suction and discharge, driven by 7½ HP electric motors through a vertical shaft. Each pump discharges 700 GPM against a total head of 20 feet.

Station #4—1938

Two Morris Pumps, vertically driven, powered by 15 HP electric motors. Each pump has 6 inch suction and discharge, and delivers 750 GPM against a total head of 50 feet.

Station #5—1940

One large Morris Pump (stand-by) has a capacity of 6,300 GPM against a total head of 37 feet. Suction diameter is 16 inches; discharge diameter, 14 inches. It is horizontally driven, through a reduction gear, by a 125 HP gasoline engine.

What Morris Pumps Do In Springfield

In one station, three Morris Pumps lift sewage and surface water to discharge the flow into the Connecticut River when flood gates are closed in the outfall sewer.

In another station, built to serve a single street, the sewage flows by gravity from the street into the wet wall of the station. It is then pumped back into the main sewer system by two Morris Pumps.

In the third and fourth stations, the sanitary sewage from low areas is lifted into the main sewer system.

The fifth station is a Main Sewage Treatment Plant, where a large Morris stand-by pump handles surface drainage...occasionally empties primary settling tanks.

Municipalities all over the country specify Morris Pumps, because of their efficiency, economy, long life and consistent output. Feel free to consult our engineers about your particular needs.

Large Cities Everywhere Depend on MORRIS PUMPS

MORRIS MACHINE WORKS
Baldwinsville, N. Y.
Sales Offices in Principal Cities

MORRIS *Centrifugal Pumps*

Submarine Filter Flood Light

Stuart Corp. of Baltimore, Md., are now building, for general use, a Submarine Filter Flood Light. The first installation will be made in the Annapolis, Md., Filter Plant.

This Submarine Light points downward and is fastened to the supply line of a Palmer Filter Bed Agitator. When the filter above the sand becomes clear enough, it is possible to see the sand boiling and the agitator turning. This is a good means of determining when the filter has been washed sufficiently.

The filter light is installed 15 in. above the top of the filter medium, and while 50 per cent bed expansion is difficult with sand, such may be obtained with Anthrafilt. When this expansion is reached the light appears to go out and indicates a point at which the back wash should be slacked off.

Information on the Submarine Filter Flood Light may be obtained from the Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

Fred Stuart Expands Service

Now Contractor of Public Works

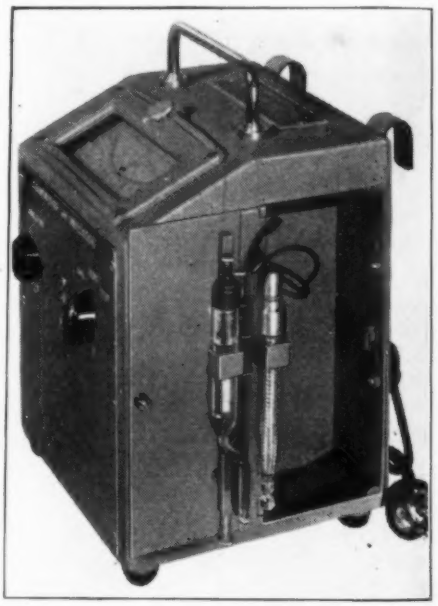
Stuart Corp., manufacturer of Activated Alum and Black-alum, developer of the Venturi-Throat Distributing Baffles-Overhead Drive, flocculation equipment, Kwik-Way mixers, automatic samplers, and manufacturers' agents for Palmer filter bed agitators, powdered activated carbon, etc., is now a contractor of public works.

Now operating under the name Stuart Corp. (formerly Stuart-Brumley Corp.), the company has expanded its services.

It has recently been awarded a contract at Annapolis for needed revisions in the water filtration plant.

Direct-Reading pH Meter

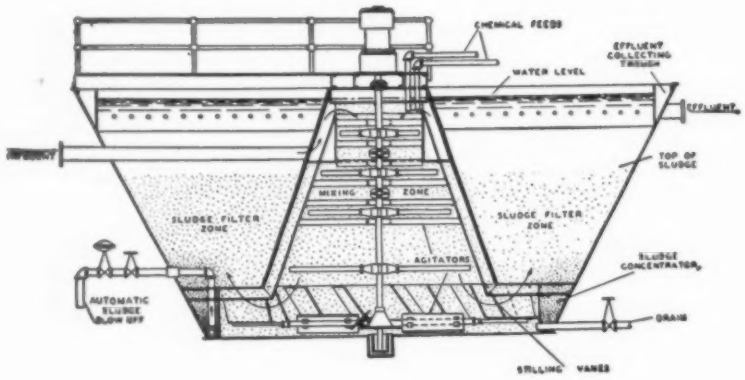
A novel direct-reading pH meter, specially designed and ruggedly built for plant applications as well as for laboratory use, has been announced by the Cambridge Instrument Co., New York.



Housed in a sturdy metal case and weighing only 10 lb., the electrode assembly, consisting of glass and calomel electrodes and resistance thermometer which provides automatic temperature compensation over a range from 0 to 100 deg. C., has an accuracy of 0.1 pH between a range of pH 0 to pH 14.

The meter operates on any 110-volt, 50 or 60 cycle A. C. outlet and requires only two adjustments for standardization. It is easy to use and complete shielding eliminates electrostatic interference. The instrument's large, clear scale is set

A new, more efficient means for removing impurities from municipal water supplies



PERMUTIT *(SPAULDING)* PRECIPITATOR

IN the Spaulding Precipitator, Permutit* has combined precipitation and separation in a single treatment step, so that water being treated flows clear from the top of the equipment.

The Vertical Precipitator, as shown schematically above, was the first development of this "sludge blanket" principle, which provides a sharp demarcation between sludge and clear effluent. Other designs are available.

Permutit Precipitators not only represent a more efficient means of cold lime treatment, but are more compact than older style methods. Permutit will be glad to cooperate with you and your consultants on any problem of producing a clear, soft, iron-free water. Many types of equipment are available, and more than 30 years' experience is at your service.

For full particulars write to The Permutit Company, Dept. W-7, 330 West 42nd Street, New York 18, N. Y., or Permutit Co. of Canada, Ltd., Montreal.

*Trademark Reg. U. S. Pat. Off.

PERMUTIT

WATER CONDITIONING HEADQUARTERS

at an angle at the top of the case so the pH value can be read at a glance. Rubber toes at the bottom of the case and hooks on the back make it possible to use either on a bench or table or to suspend over vat or tank, or to mount on a wall.

Further information on this unit may be obtained from the Cambridge Instrument Co., Inc., 3751 Grand Central Terminal, New York 17, N. Y.

Eastern Sewage Disposal Co., Inc.

Promotes Contact Aeration Process

The Eastern Sewage Disposal Co., Inc. of Washington, D. C. is now promoting the Hays-Schulhoff-Griffith process of domestic sewage disposal in the Atlantic Coast states. This Hays-Schulhoff-Griffith process, more familiarly known as the Hays Process of Contact Aeration, has been in use for more than twelve years, and has been installed in 120 odd plants in 22 states. These plants serve populations ranging from 500 to 40,000 and are located principally in Texas, where the process was originated.

The process is offered as a biological treatment for industrial and domestic waste and involves the use of submerged contact surfaces between which the distributed air rises to the liquid surface.

The Eastern Sewage Disposal Co., Inc. is represented by Homer Trimble, Atlantic Bldg., Washington 4, D. C.

New Aluminum Ladder

A new aluminum ladder weighing but slightly over one pound per foot and safe for a 250 lb. load has been announced by the Aluminum Ladder Co. of Worthington, Pa.

This new featherweight model is economically designed for light industrial, home, and farm uses. Its advantages lie in the fact that the aluminum will not rot or rust, it can be washed or scalded without impairing its strength, and its rungs are corrugated for safe footing. Sizes range from 6 to 16 ft. lengths, and two of the 8, 10, and 12 ft. length ladders can be joined to form an extension ladder.

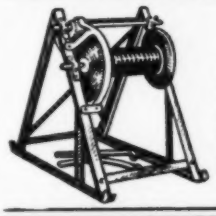
Further information on this new aluminum ladder may be obtained from the Aluminum Ladder Co., Carbis St., Worthington, Pa.

FILER & STOWELL SLUICE GATES

are built to stand long hard usage. Amply proportioned for all stresses of shipment, erection and operation. They may be obtained with manual, hydraulic cylinder or motor operating controls.

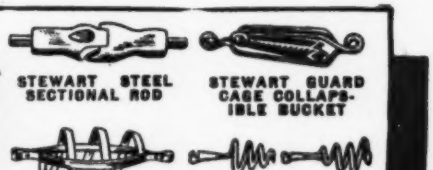
THE FILER & STOWELL COMPANY
MILWAUKEE 7, WISC.

Your **PIPE CLEANING PROBLEMS SOLVED**



STEWART STANDARD WINDLASS

Frame. Sturdy angle iron construction. Cable drum holds 1100 ft. of ⅜" cable. Shipping weight without cable 250 lbs.



STEWART STEEL SECTIONAL ROD — STEWART GUARD CAGE COLLAPSIBLE BUCKET

NO. 9A STEWART WELDED ROOT CUTTER — NO. 11—SCREW NO. 22—SPEAR SCREW

For information write for catalog.
Canadian Distributors: W. H. Cunningham & Hill Ltd., Toronto.

W.H. STEWART
1051 SOUTH CLINTON ST
SYRACUSE, N.Y.

Hazleton Type "M"

CHECK VALVE

with Built-in Mercoid Motor Shut-off Switch for Automatic Pump Protection

PROTECTS PUMP FROM DAMAGE DUE TO LOSS OF WATER

PREVENTS OPERATION OF PUMP UNTIL PROPERLY PRIMED

Flow switch insures pump against damage in event pump loses water during operation. Mercoid switch is actuated by valve-flap. Switch is connected into no-voltage coil of motor starter.

Write for Further Information.

BARRETT, HAENTJENS & CO.
HAZLETON PENNSYLVANIA

WATER MAINS DISINFECTION:

We provide chemicals, equipment, and experienced operator ready to serve you within 200 miles of Washington, D. C. Write or telephone us for information.

WOOD & PREUIT COMPANY
1740 K Street, N.W.
Washington 6, D. C.
Telephone National 2125

Northrop & Co. Moves Main Sales Office

Northrop & Co., Inc., manufacturers of Bond-O, self-caulking jointing compound, has announced a change of address as of June 15, at which time they moved their main sales office from its location at 50 Church St., New York City, to their works at Spring Valley, N. Y. The new address will be Northrop & Co., Inc., Spring Valley, N. Y.

New Fairbanks Morse Motor

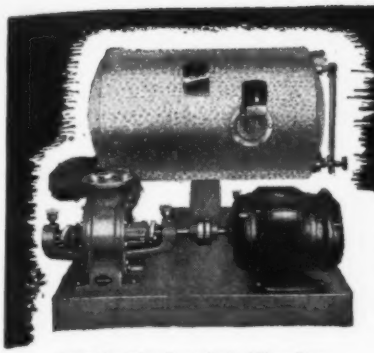
Fairbanks, Morse & Co., Chicago, has announced an entirely new type of electrical motor designated as the Axial Air-Gap—a radical departure in design from standard motors. The principles of the axial air-gap motor are revolutionary. It is distinguished by the fact that the magnetic lines of force follow a path parallel to the shaft, or axis of rotation, as compared to a radial path taken by the magnetic flux in the conventional motor.

Several thousand of these motors are now in service and this line of motors ranges in size from ⅓ to 10 hp. The motors are suitable for horizontal or vertical flange mounting, or for an angle base for belt drive.

Outstanding features are space and weight reduction, the new motor being less than half the size of the conventional type motor and weighing less by approximately 30 per cent. It also has improved appearance, and simplicity and speed with which it can be inspected, cleaned, and lubricated, as well as cooler operation.

The accompanying photograph shows a comparison of the conventional construction (left) with the new axial air-gap construction of a motor of the same rating.

Further information on this unit may be obtained from Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.



CONDENSATE RETURN *at its* BEST

Capacities to 150 G.P.M.
(Both Horizontal and Vertical)

APCO Horizontal Simplex Condensation Return Unit

These units are available in simplex and duplex types—designed for the automatic return to high and low pressure boilers of the hot water condensation from radiators, coils, etc. Catalogued in sizes ranging from 2,000 to 100,000 sq. ft. equiv. radiation. Larger sizes available.

APCO TURBINE-TYPE PUMPS

Apcos are ideal for the above service or any small capacity, high head duty. The one moving part, the impeller, is free running, therefore unaffected by heat expansion. Ability to maintain practically constant capacity against drastic pressure conditions is another of many distinctive features.

AURORA CENTRIFUGALS
for Every Pumping Job
HORIZONTAL SPLIT CASE
Single & Two Stage
SIDE SUCTION
VERTICAL
NON CLOG
SUMP
MIXED FLOW
SPECIAL DESIGN
Write for
CONDENSED CATALOG "M"
or
Consult SWEETS

DISTRIBUTORS IN PRINCIPAL CITIES

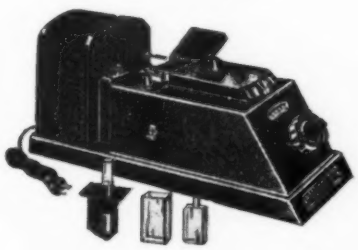
AURORA Always PUMPS

AURORA PUMP COMPANY

68 Loucks Street, AURORA, ILLINOIS

KLETT SUMMERSON ELECTRIC PHOTOMETER

Adaptable for Use in Water Analysis



Can be used for any determination in which color or turbidity can be developed in proportion to substance to be determined.

KLETT MANUFACTURING CO.
179 EAST 87th STREET • NEW YORK 28, N. Y.

ELECTRONIC COAGULATION

***NOW* in Successful Commercial Use!!**

Largest installation now treating 1,500,000 gal. per day in a municipal plant.

We can design and furnish Electronic Coagulators which will remove color and turbidity from water supplies.

Inquiries invited.

ELECTRONIC PURIFICATION CORPORATION

516 N. Charles Street Baltimore, Md.

Water Meter Scale Solvent

The Skasol Corp. of Webster Groves, Mo. is now marketing a mild scale solvent known as Nu-Coil. Nu-Coil will remove scale deposits on water meters with rapid action, but it is safe for the mechanic to handle and will not attack the delicate water meter equipment to be cleaned. It will attack aluminum. It will not attack rubber and the directions call for the meter to be completely disassembled and submerged, including the register box and all, in the solution.

When the scale is removed, all parts are to be rinsed in hot water, dried, and oiled with a good grade of fine oil, and assembled. If meters are not immediately assembled, all parts should be dipped in a "Stop It" solution which stops oxidation after descaling or cleaning.

This solution may be reused repeatedly and does not deteriorate with age.

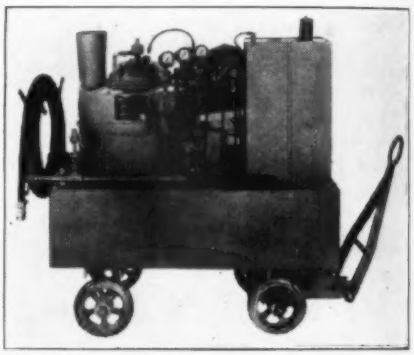
If action of descaling appears too rapid, the Nu-Coil solvent may be diluted with as much as five parts of water without decreasing its effectiveness, although decreasing the rapidity with which the action takes place.

Further information on Nu-Coil Water Meter Scale Solvent may be obtained from the Skasol Corporation, 112 Glencoe Ave., Webster Groves 19, Mo.

Oakite-Vapor Steam Cleaning Unit

Oakite Products, Inc. of New York has announced the immediate availability of a new, improved Oakite-Vapor Steam Cleaning Unit for use in cleaning and paint-stripping a wide variety of industrial equipment and plant facilities.

The unit is an enclosed coil type, down-draft flame steam generator, which delivers a hot vaporized spray in either wet or dry state under pressures up to 200 lbs. With a 12-gallon fuel capacity tank, the



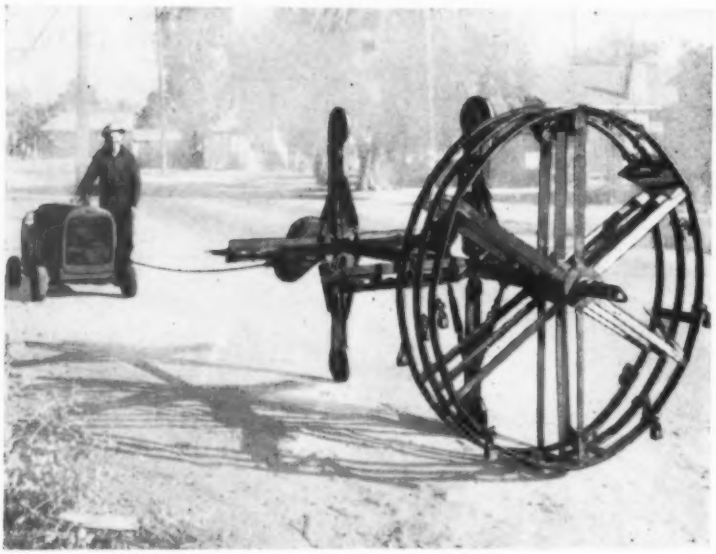
unit provides ample steam generation for an uninterrupted eight-hour, two-gun cleaning cycle.

The unit is available as a stationary model, or mounted on a shop wheel chassis for portability, or mounted on a trailer type chassis. A ¾ hp. 60 cycle, 110-220 v. ac motor is rigidly mounted on the unit.

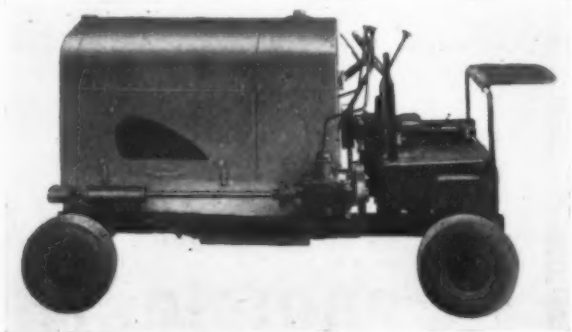
Steam cleaners of this type may find considerable use in cleaning and preparation of services around water and sewage works. They are particularly applicable to such cleaning problems as sedimentation tanks, grit chambers and clarifiers in sewage treatment works being cleaned for painting. Sewage plants using this type of equipment have found it invaluable in preparing dirty and greasy surfaces for painting and protective coating. It also has a value in cleaning sludge lines and other pipe lines on which a grease ring has formed and the capacity of the line has suffered in consequence.

A complete description of the construction, operation, mainte-

RELINING LARGE PIPE?



No cement-lined jobs have ever given any trouble where the pipe was properly cleaned. "Flexibles" take off all the scale down to the metal itself. It may, indeed, cost a few cents more, but it's tops in insurance on large projects. For further information or catalogs, write Dept. 7 today.



1947 Model "Flexible" Power Drive

FLEXIBLE UNDERGROUND PIPE CLEANING CO.

9059 Venice Blvd., Los Angeles 34, California

855 Board of Trade Bldg. Chicago 4, Ill.
401 Broadway New York 13
147 Hillside Ter. Irvington, N. J.
P. O. Box 185 Atlatna
41 Greenway St. Hamden, Conn.
1624 Harmon Place Minneapolis 3, Minn.
29 Cordan Ave. Roslindale 31, Mass.
P. O. Box 694 Pittsburgh
P. O. Box 447 Lancaster, Texas

nance, and job applications of this steam cleaner may be obtained by writing Oakite Products, Inc., 157 Thames St., New York 6. N. Y.

Plastic Comparators

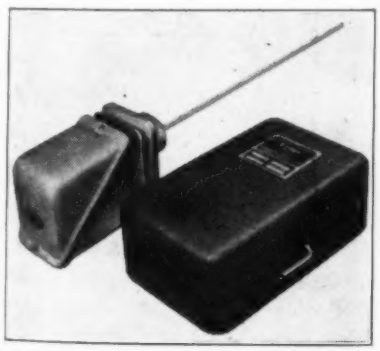
A new plastic comparator for use in water and sewage works for the determination of pH, chlorine, phosphates, etc., is now produced by the LaMotte Chemical Products Co.

These new LaMotte plastic comparators are non-corrodible and can be used under conditions of moisture and splash involved in heavy processing work. They are easily handled and the color fields produced in the new comparator are improved through a tapering arrangement in the plastic mold.

Further information on the La Motte plastic comparators may be obtained from the LaMotte Chemical Products Co., Towson 4, Baltimore, Md.

Gas Flame Failure Safeguard

Combustion Control Corp. has introduced a new Fireye flame failure safeguard for boiler protection. This



Fireye Electric Flame Rod Type 45 JQ1 brings to the combustion field the most advanced electronic design incorporated in several complete combustion control systems and is applicable to all types of gas-fired burners.

Fireye is a foolproof electronic flame failure safeguard which actually "feels" the gas flame. It maintains a constant vigil against the ever present danger of flame failure. When the flame does fail, it instantly cuts off fuel and can be wired to sound an alarm automatically. Unlike thermal controls, Fireye responds to the flame itself, not to a secondary effect of the flame.

Further information on this Fireye Flame Failure Safeguard may be obtained from the Combustion Control Corp., 77 Broadway, Cambridge 42, Mass.

Steam Cleaner

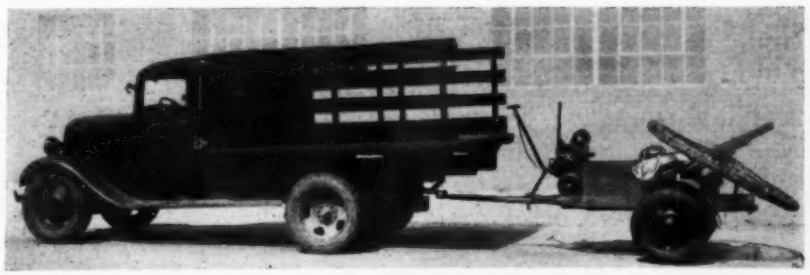
The Clayton Manufacturing Co. has announced the new Model C Kerrick Kleaner, developed during the war to simplify steam cleaning under rigorous conditions. The Model C is completely new in design and embodies a number of features never before offered. The unit is fully streamlined and compactly self-contained in a vapor and dust-proof cabinet.

Further information on the Model C Kerrick Kleaner may be obtained from the Clayton Mfg. Co., Los Angeles, Calif.

WANT THIS?

PRESENT FLEXIBLE USERS, PLEASE NOTE: For some years past, we have had many inquiries for a practical, "Flexible" trailer or "Carryall." Designed for use in carrying rods, pipe guide, power drive, operating tools, hose, picks, shovels, bucket, rope and red flags. Everything needed in one mobile unit. Take it to the job and leave it. Relieve stand-by truck for other service.

We're depending on you "old timers" to write us. Let us know if you want this trailer manufactured. We have many other items we can make, and must use our factory facilities to serve you best. Yes or no, we want to hear from you. Write Dept. 8 today.



FLEXIBLE SEWER-ROD EQUIPMENT CO.

9059 Venice Blvd., Los Angeles 34, California

855 Board of Trade Bldg. Chicago 4, Ill.
401 Broadway New York 13
147 Hillside Ter. Irvington, N. J.
P. O. Box 165 Atlatna
41 Greenway St. Hamden, Conn.
1624 Harmen Place Minneapolis 3, Minn.
29 Cerdan Ave. Reslindale 31, Mass.
P. O. Box 694 Pittsburgh
P. O. Box 447 Lancaster, Texas

New Type Compound Meter

The Challenger Manufacturing Co. of San Jose, Calif., has introduced a new type of meter to the water works field. Neither a copy nor a refinement of any existing type of meter, this new method of metering large flows does so with great accuracy and an unusually low head loss. It is the outgrowth of an hydraulic device developed by the Navy during the war and has been proven by extensive use over a period of three years.

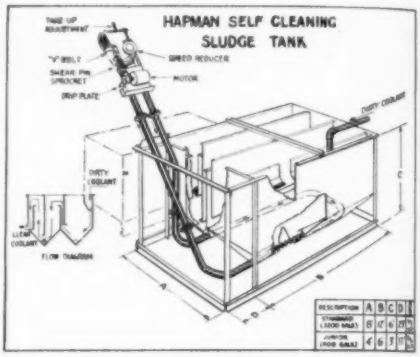
Advantages of this Challenger Fluid Meter include a low head loss of not more than 5 psi. at 700 gpm. for a 4-inch meter; accuracy of registration as low as 1.5 gpm. flow on a 4-inch meter; flow characteristics of proportional type meters; no change-over characteristics of the usual type compound type meter; standard length and flange specifications; self-contained calibration unit; single register, etc.

The new meter complies with the A.W.W.A. specifications for disk, current, and compound type meters for capacity and loss of head tests.

Further information on the Challenger Meter may be obtained from the Challenger Mfg. Co., 41 Wilson Ave., San Jose, Calif.

Self-Cleaning Sludge Tanks

Hapman Conveyors, Inc., of Detroit have introduced self-cleaning sludge tanks. The self-cleaning is accomplished by pipe conveyors having synthetic rubber flights mounted on sealed pin chains. The conveyors will operate in any plan and constitute a radical departure from ordinary tanks in that they operate in a double "V" bottom which permits rapid sludge settling and quick removal.



These tanks are offered particularly for any non-corrosive sludge which will settle readily. They can be used in industries, for example, where quench tank scale, machine tool coolant settlings, and abrasive precipitates are typical materials to be handled. Temperature is limited to 270 deg. F. There are two sizes, the Junior size with a capacity of 400 gals. and the Standard size of 3200 gals.

These self-cleaning sludge tanks may find use in many industrial plants where pre-treatment to remove solids is desired before waste is discharged to the city sewer.

Further information on these self-cleaning sludge tanks may be obtained from the Hapman Conveyors, Inc., 2405 W. McNichols, Detroit 21, Mich.

Plastic Pipe Used in Airplane Water Lines

Boeing's new Stratocruiser is fitted with 435 ft. of Tenite (plastic) water pipe. Previous experiences in 'round-the-world transport airplane service indicated that differences in mineral content of water throughout the world set up chemical reactions in metal pipes, often resulting in drinking water that was unpalatable. Plastic tubing shows no such reaction.

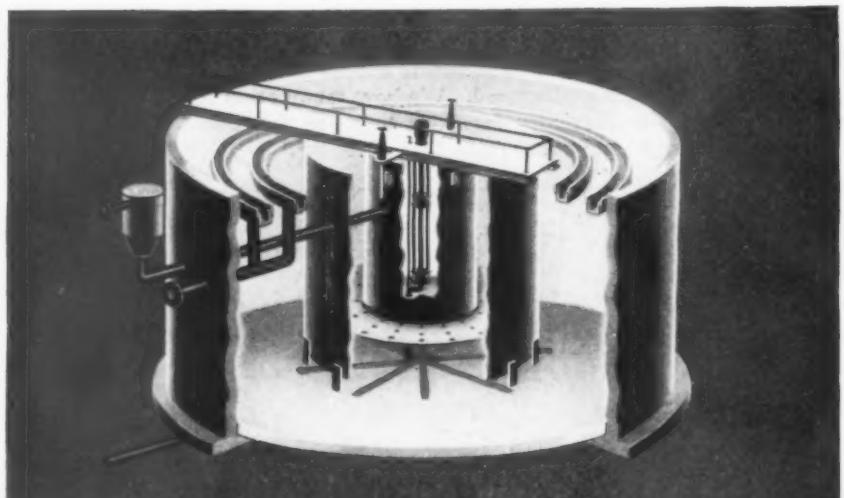
FOR WATER SOFTENING . . . TURBIDITY AND COLOR REMOVAL
. . . INDUSTRIAL WASTE TREATMENT . . .

The Clariflow

with independently-operated mixing, flocculation, stilling and sedimentation zones

A notable improvement over conventional short-retention water treatment units. Provides individual functioning of mixing, flocculation, stilling and sedimentation zones. • Its control over short-circuiting, control over each function and control of sedimentation through low weir rates mean improved effluent . . . higher filtration rates . . . longer filter runs . . . better industrial waste recovery and treatment.

Write for Bulletin 656



WALKER PROCESS EQUIPMENT INC.
YEARS OF EXPERIENCE TOGETHER IN EQUIPMENT ENGINEERING
AURORA • ILLINOIS
PROQUIP

Before installing the plastic pipe, extensive taste tests were conducted to check the potability of water after it had passed through Tenite. Water in which the plastic had been submerged for prolonged periods was sampled by a number of persons and found to be unaffected as to taste.

The Tenite tubing to be used in the Stratocruiser ranges in size from ½ to 1 inch outside diameter. Tenite is a cellulose acetate butyrate and the connecting joints are short lengths of pliable polyvinyl chloride, secured by two light weight, quick action metal clamps. Most of the valves are aluminum alloy, coated with an organic finish as protection against chemical reactions. Water will be furnished from three main tanks with a total capacity of 77 gallons. All will be filled from a single ground connection.

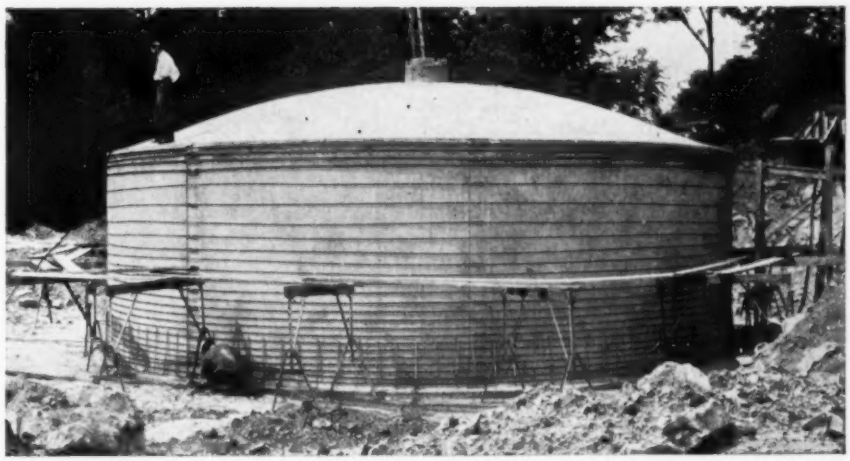
"Tenite" is a product of the Tennessee Eastman Corp., Kingsport, Tenn.

Boiler Feed-Water Controller

A new type boiler feed-water control, called the Micro-Netic Electric Controller, has been developed by the J. A. Campbell Co. of Long Beach, Calif. Weighing but 7½ pounds, it can be attached to a boiler to occupy a space 3½x7½ inches for its housing and with a switch box measuring 2x4x6½ inches.

The Micro-Netic embodies a round ball float of monel, capable of resisting pressures up to 400 psi. The float carries a steel ring which attracts magnets when the ring comes into their fields. Alnico permanent magnets are used in connection with a Micro-switch, and when the water level reaches a predetermined point, the magnetic action opens the water line and vice versa.

Literature describing the Micro-Netic may be obtained from the J. A. Campbell Co., 645 E. Wardlow Road, Long Beach 7, Calif.



• PRE-STRESSED "GUNITE" •

The picture shows a partially completed 40' diameter, 110,000 gallon pre-stressed "GUNITE' tank with a "GUNITE" dome roof, designed and built by us.

When this photo was made the tank was filled with water for leakage test. After the test showed the tank to be bottle-tight, two inch mesh reinforced "GUNITE" was placed over the outside to permanently protect the pre-stressed hoop rods. The tank was subsequently covered with earth, with 12" of fill over the dome.

This photo illustrates our method of pre-stressing the hoop rods by means of several turnbuckles in each hoop.

Our Bulletin C2300 describes and illustrates prestressed "GUNITE" construction in detail and also scores of other uses of "GUNITE."

Write today for your free copy of Bulletin C2300.

CEMENT GUN COMPANY
"GUNITE" CONTRACTORS
GENERAL OFFICES—ALLENTOWN, PENNA., U.S.A.

PAYNE DEAN GATE OPERATOR

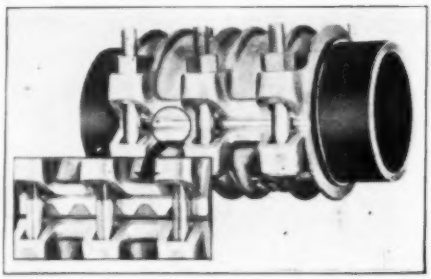
NEW! NEW!

SOMETHING NEW FOR QUICK OPERATION OF GATES TO 30 IN. A PORTABLE GAS ENGINE DRIVEN GATE OPERATOR-UNLOAD IT AT THE JOB AND LET THE TRUCK GO ABOUT ITS REGULAR BUSINESS. ONE MAN CAN HANDLE THE LITTLE FELLOW. 6 H.P. MOTOR. HUSKY, STRONG (450 LBS.) BIG TIRES AND BALL BEARING WHEELS FOR ROUGH GROUND. SAFETY SHEAR COUPLING-REVOLUTION COUNTER AND REVERSE GEAR. SPEED RANGE 15 TO 30 TURNS A MINUTE.

PAYNE DEAN & CO., MADISON, CONN.

Bronze Repair Clamp

Smith-Blair Co. of San Francisco has announced a new cast bronze full circle repair clamp of simple construction that requires only six minutes for installation. Installation requires simple bolting together of the two halves of the coupling over the broken or split cast iron or cement-asbestos pipe. The use of bronze for the coupling and duronze nuts and bolts assures permanence of the repair.



The new clamp employs a unique feature in that it forms a complete water-tight circle that compensates expansion and contraction of the pipe. Special molded rubber gaskets with copper armor are bonded to the inside of the coupling sleeves. Of special design, this rubber gasket cannot wrinkle or gather under the coupling. The result is a complete, strong encirclement with pressure so well equalized that even weak-walled pipes are not crushed. The coupling resists leaking at the pressures of 1,000 psi.

Further information on this bronze repair clamp may be obtained from the Smith-Blair Co. of South San Francisco, Calif

FOR
WATER CONDITIONING

SOLVAY
TRADE MARK REG. U. S. PAT. OFF.

For Water Softening

• • • SOLVAY SODA ASH

For Water Purification

• • • SOLVAY LIQUID CHLORINE

For Water Technical Service

• • • Call SOLVAY

SOLVAY SALES CORPORATION
Alkalies and Chemical Products Manufactured by The Solvay Process Company
40 Rector Street New York 6, N. Y.

BRANCH SALES OFFICES
Boston • Charlotte • Chicago • Cincinnati • Cleveland • Detroit • Houston
New Orleans • New York • Philadelphia • Pittsburgh • St. Louis • Syracuse

Burrell Offers Deci-Log Slide Rule

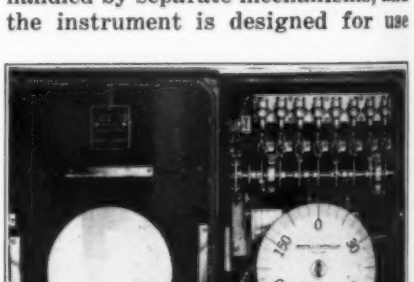
Burrell Technical Supply Co. has announced a new Deci-Log Log Slide Rule which has 16 scales and a number of advantages, including the fact that reciprocals can be read with the decimal point placed.

Further information about this Deci-Log Log Slide Rule may be obtained from the Burrell Technical Supply Co., 1936-42 Fifth Ave., Pittsburgh 19, Pa.

Bristol's New Time Cycle Controller

The Bristol Co. of Waterbury, Conn., has announced a new multiple-cam time cycle controller, known as Model C500 Impulse-Sequence Cycle Controller. These are for timing mechanical operations in industrial processes.

In this controller, time measurement and pilot valve operation are handled by separate mechanisms, and the instrument is designed for use



on plant processes where such factors as opening and closing of valves, switches, dampers, retorts, presses, and the starting, stopping, or reversing of motor-driven pumps and blowers must be accurately timed according to a fixed program.

Further information on these controllers, which are drilled for eight cams and pilot valves, may be ob-

tained from The Bristol Company, Waterbury 91, Conn. Write for Bulletin C305.

Postal Scale

A new small home and office postal scale, Model 101A, has been announced by the Accurate Parts Mfg. Co., Cleveland. The scale is all metal and has a cantilever spring for accuracy. It carries domestic rate tables has a weighing range of 12 ounces, is easily adjustable to zero, and is obtainable in a choice of colors —green, red, or ivory.

For further information write Accurate Parts Mfg. Co., 12435 Euclid Ave., Cleveland 6, Ohio.

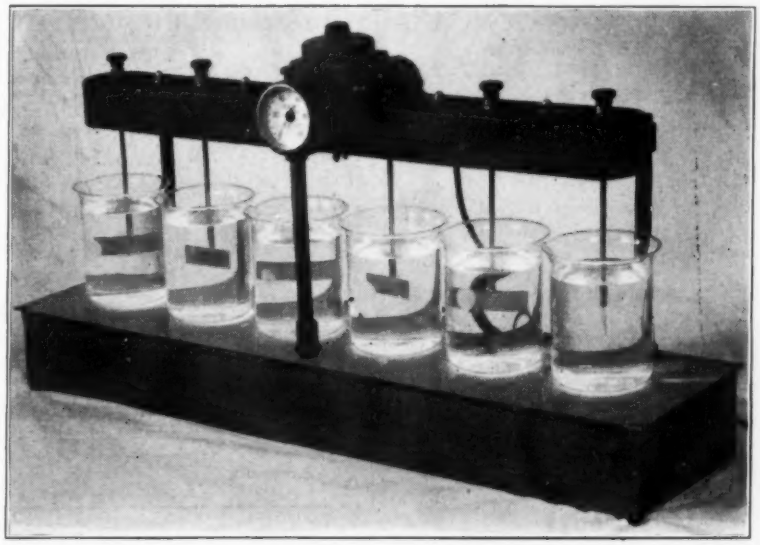
Nickel Alloys Selector

The Nickel Alloy Selector, issued by the International Nickel Co., Inc., of New York, is a piece of equipment that will find ready use by designers and chemical engineers. It will also be of interest to managers, superintendents, and chemists in water and sewage works who may have an interest in information on monel, nickel, and nickel alloy materials.

This Inco Nickel Alloy Selector may be obtained from The International Nickel Co., Inc., 67 Wall St., New York 5, N. Y.

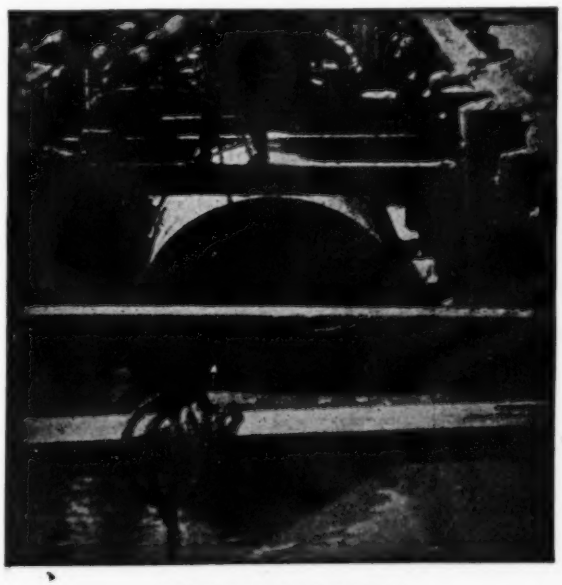
This particular device, 7¾ x 11 in. in size and carried in a neat envelope jacket, is a slide rule type of device from which it is possible to obtain the chemical composition, physical constants, yield strength, tensile strength, elongation, hardness, toughness, and other information on eight different nickel alloys in any one of eight different forms from rod and bar to castings. Merely by setting the arrow at the type of metal in which you are interested and setting a sliding disc at the form of metal desired, you may determine the various factors and information about the alloy in question.

THE *Phipps & Bird* LABORATORY MIXER . . .



IS the important piece of equipment in the Modern Water Works Laboratory. Now being used by leaders in water works research. Many superintendents and chemists have been able to reduce their chemical costs by the control of chemical dosages with this mixer. Write for literature.

PHIPPS & BIRD, INC.
RICHMOND, VA.
"SOUTHERN CENTER FOR LABORATORY APPARATUS AND CHEMICALS"



84" pipe—Spring Lake, N. J.

FLANGED PIPE
FLEXIBLE JOINT PIPE
BELL & SPIGOT PIPE
SPECIAL CASTINGS
SHORT BODY BELL & SPIGOT SPECIALS

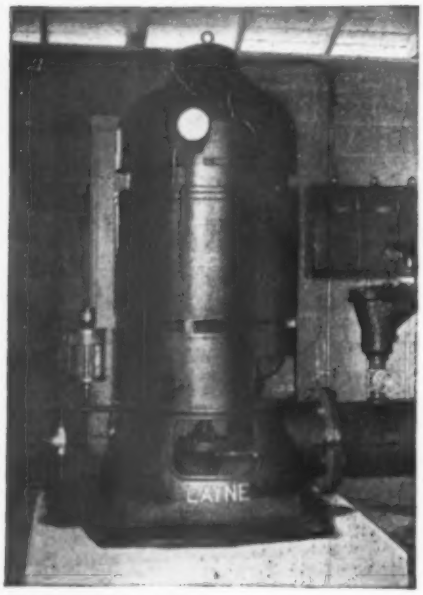
Large stock enables us to make prompt shipments.

CAST IRON PIPE

SIZES 3" TO 84"

Warren Foundry & Pipe Corp.
11 Broadway, New York

Warren Pipe Company of Mass., Inc.



DOWN IN WARRINGTON, FLORIDA

Back in 1937, when the Peoples Water Service Company bought their first Layne Well Water System to serve the city of Warrington, Florida, they had only 263 connections. But Warrington, being a fine home city, grew larger and larger. By 1941 a second unit was needed, and being guided by an appreciation of known quality, none but a Layne Well Water System was to be considered. In 1945, connections had increased to 3,200, so again additional water supply was needed.

Peoples Water Service Company now have their third Layne Water System . . . one of the finest and most complete in the entire state. Powered with a 100 h.p. electric motor, turning at 1170 r.p.m., this new system is producing 1150 gallons of water per minute. The well is underreamed and packed with 20 yards of sized gravel.

Standardization on Layne Well Water producing equipment, was a very wise move. Production cost of water is exceptionally low and dependability of equipment is a major asset.

For further information on Layne Well Water developing service, address Layne & Bowler, Inc., General Offices, Memphis 8, Tennessee.

***LAYNE PUMPS* for lakes, rivers, reservoirs, irrigation, for any use where large quantities of water must be produced at low cost. Sizes range from 40 to 16,000 gallons per minute, powerd by electric motor, V-belt or right angle gear drives. Write for Layne Pump Catalog.**

LAYNE

WELL WATER SYSTEMS
Turbine Pumps

AFFILIATED COMPANIES: Layne-Arkansas Co., Stuttgart, Ark. ★ Layne-Atlantic Co., Norfolk, Va. ★ Layne-Central Co., Memphis, Tenn. ★ Layne-Northern Co., Mishawaka, Ind. ★ Layne-Louisiana Co., Lake Charles, La. ★ Louisiana Well Co., Monroe, La. ★ Layne-New York Co., New York City ★ Layne-Northwest Co., Milwaukee, Wis. ★ Layne-Ohio Co., Columbus, Ohio ★ Layne-Pacific, Inc., Seattle, Wash. ★ Layne-Texas Co., Houston, Texas ★ Layne-Western Co., Kansas City, Mo. ★ Layne-Western Co. of Minn., Minneapolis, Minn. ★ International Water Supply Ltd., London, Ont., Can. ★ Layne-Hispano Americana, S. A., Mexico, D. F.

Kayser Supervises Falk Corp. Development

The Falk Corp. of Milwaukee, Wis., manufacturers of gear equipment, has announced the appointment of Henry W. Kayser as Supervisor of Development Engineering. Mr. Kayser has been associated with The Falk Corp. as a designer, application engineer, and development engineer since his graduation from Marquette University in 1931.

LITERATURE AND CATALOGS

"Clean Waters" Movie Aids City

A story in **Load**, issued by the General Electric Co., tells how Modesto, Calif., having outgrown its sewage system, conducted a successful campaign to obtain approval of a bond issue. Modesto now has a population of 24,000 people with 15,000 living in the adjacent area, yet the sewer system was built in 1910 for a city of 8,000 and the sewage plant was built in 1932 and 1938 when the population was half of that. As a result of this overload, the nearby river was grossly polluted.

According to Robert W. Cowden, Manager of the Chamber of Commerce, who wrote the article, the Modesto Chamber of Commerce assumed a special bond election advertising campaign because it considered it the most important project facing the city. As a part of the campaign the General Electric film "Clean Waters" was shown to over 50 social, civic, and fraternal organizations in the community. The Chamber of Commerce also distributed bumper strips, gave a series of prepared radio addresses, obtained the editorial backing of the newspapers, and made a house-to-house canvass. As a result of these efforts the sewage treatment works proposition was approved by a vote of eleven to one.

The new domestic sewers will cost $738,000, industrial sewers will cost $613,000, and the water storage facilities will be increased at a cost of $300,000.

Copies of **Load** may be obtained from the General Electric Co., Schenectady, N. Y.

GOLDEN-ANDERSON

Design and Build

OVER 1500

TYPES AND SIZES IN

AUTOMATIC

VALVES

For Engineered Protection on any HIGH PRESSURE INSTALLATION

● **Make Golden-Anderson Valves your first choice on any new or replacement project—for maximum safety, dependability and protection.**

Descriptive Technical Catalog on request.

GA
GOLDEN-ANDERSON VALVE Specialty Company
PITTSBURGH 22, PA

FINE SCREENS
FOR
SEWAGE
AND
INDUSTRIAL WASTES
TREATMENT

FORMER CONCEPTIONS COMPLETELY OUTMODED

NO COSTLY, POWER CONSUMING REVOLVING BRUSH ARMS—25% GREATER SUBMERGED AREA.

NEW SCREEN PLATES FOR THE ECONOMICAL USE OF A FILTER MEDIA ON THE SCREEN, THUS INSURING GREATER REMOVALS THAN POSSIBLE HITHERTO.

COMPLETELY AUTOMATIC CONTROL POSITIVE SEAL RINGS.

MODERN DESIGN
HIGHEST EFFICIENCIES
LOWEST COST

SANEQUIPMENT ENGINEERING
2843 WHITEWOOD AVE.
ANN ARBOR, MICHIGAN

DESIGNERS — CONSULTANTS

Programmed Pumping Control

In Bulletin S-7 of the Automatic Control Co. of St. Paul, Minn., the means for coordination of operations and maximum pumping efficiency as provided in programmed control is presented. These **Selectrols Type M** are automatic control units for programmed multiple circuit operations for sewage disposal plants and water systems. The standard Selectrol is available for the control of from two to eighteen circuits singly or in combination over any desired float travel up to 40 ft.

The four-page bulletin presents the Electrol features which include differential compensator, the lost motion clutch to prevent hunting by the pumps, adjustability, corrosion resistance, mechanical construction, and operating convenience. The bulletin also shows cutaway drawings of the construction details and Selectrol accessories and spare parts.

Bulletin S-7 on Type M Selectrols may be obtained by writing the Automatic Control Co., 1005 University Ave., St. Paul 4, Minn.

A New Item by LaMotte

ALGAE TREATMENT

Simplified by LaMotte D.M. Tube Inversion Rack

An accurate method for predetermining the effective dosage of Copper Sulphate in Algae Control. (Ref. William D. Monie, Water and Sewage Works, 93, 173-176, 1946).

The LaMotte D.M. Tube Inversion Rack, complete with 6 matched graduated tubes with stoppers, $15.00 f.o.b. Towson, Md. Reagents and glassware to complete the apparatus for this test supplied at standard prices.

Write for descriptive literature

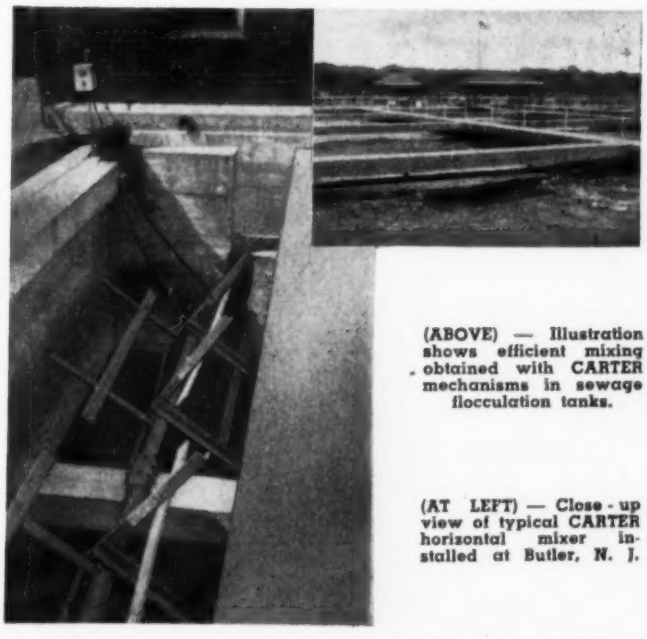
LaMOTTE CHEMICAL PRODUCTS CO.

Dept. WSW **Towson 4, Md.**

50th ANNIVERSARY 1897-1947

MECHANICAL CARTER MIXING EQUIPMENT

• *WRITE FOR BULLETIN No. 4507*



(ABOVE) — Illustration shows efficient mixing obtained with CARTER mechanisms in sewage flocculation tanks.

(AT LEFT) — Close-up view of typical CARTER horizontal mixer installed at Butler, N. J.

For flocculation or pre-flocculation prior to settling, CARTER custom-built mixing equipment operating either independently or in conjunction with air, materially aid the coagulent by promoting floc amassment at a velocity just sufficient to prevent sedimentation.

May we recommend the services of one of our engineers to assist you on your next design—no obligation of course.

RALPH B. CARTER CO.

HACKENSACK NEW JERSEY

NEW YORK OFFICE: 53 PARK PLACE, NEW YORK 7, N. Y.

Leopold

• **GLAZED FIRE CLAY TILE FILTER**

Non-corrosive, permanent.

• **DRY CHEMICAL FEEDERS**

Compact, light in weight, durable, accurate. Sizes and capacities to suit any operating requirements.

• **COMPLETE WATER TREATMENT AND FILTER PLANT EQUIPMENT**

Designed and built by Leopold engineers to handle any service.

Write today for complete information.

F. B. LEOPOLD CO., INC.
2413 W. CARSON ST. PITTSBURGH 4, PA.

WILL SELL

all or part 500 tons miscellaneous cast iron water fittings, sizes ranging from 4" to 20", located Jacksonville, Florida.

Phone, Wire, or Write —

Albert Pipe Supply Co., Inc.
Berry and N. 13th St.
Brooklyn 11, N. Y.
EVERGREEN 7-8100

Sewer Cleaning Machine

A four-page circular describing the **Flexi-Cleaner,** an electric motor-powered sewer and pipe line cleaning machine, has been issued by the Flexible Sewer-Rod Equipment Co. of Los Angeles.

The circular contains complete details concerning the portable, three-speed, reversible power cleaner. Photographs show actual applications in waste and sewer lines, with both flexible steel as well as coiled cleaning rods. Various cutting head tools for use with both coiled and steel rods are illustrated and described.

For a copy of this circular describing the Flexi-Cleaner, write to Flexible Sewer-Rod Equipment Co., 9059 Venice Blvd., Los Angeles 34, Calif.

Allis-Chalmers Annual Review

The year 1946 marked the one hundredth year of the Allis-Chalmers Mfg. Co. of Milwaukee, and the **Allis-Chalmers Annual Review** for that year has just been released.

This bulletin shows the products of the company and their application in various phases of industry. Included in the bulletin are pictures and descriptions of power generation, power distribution, and equipment for these industries: Metals, coal, rock products, construction and public works (water and sewage works), chemical, petroleum, forest products, farming, food, as well as general industrial uses, transportation, national defense, and research.

Although water and sewage works represent but a small part of the varied industrial equipment, it is obvious that water and sewage treatment play an important part in the field of industry and human relations.

For the past several years it has not been possible for Allis-Chalmers Co. to offer the annual review for unlimited distribution, but with this issue they announce that it may be obtained by anyone desiring a copy.

Write to Allis-Chalmers Mfg. Co., Box 512, Milwaukee 1, Wis.

Packing

The problem of selecting the correct packing for use in water and sewage treatment plants has always been of particular interest to operators of these plants. A survey of our readers at one time indicated

How to Speed Up Meter Repairs

To expedite meter repairs, first clean gear trains and other meter parts with Oakite. This fast-acting material does an amazing job of removing muck and grease. Next, apply Oakite Compound No. 32 to get rid of water scale. Then rinse. Parts come out clean, ready for quicker repair and reassembly.

GET NEW ECONOMY SIZE OAKITE COMPOUND NO. 32 TODAY!

Oakite Compound No. 32, an inhibited acidic scale dissolver, may be obtained in one-gallon containers . . . four to the case. Order new economy size today.

OAKITE PRODUCTS, INC.
73 Thames Street, NEW YORK 6, N. Y.
Technical Representatives in Principal Cities of U. S. & Canada

OAKITE
Specialized Industrial Cleaning
MATERIALS • METHODS • SERVICE

LEADITE
The Pioneer Self Caulking Material for C I Pipe
— withstands severe VIBRATION

—on c. i. bell and spigot pipe lines running over, or suspended from, bridges, under railroad or trolley tracks, etc. In fact, Leadite has been called upon to meet most every condition common to water main construction.

THE LEADITE COMPANY
Girard Trust Co. Bldg., Philadelphia 2, Pa.

No Caulking

great interest in packing, its use and proper handling. It will be of interest to a number of readers, therefore, to see a catalog titled **Palmetto Packings,** issued by Greene, Tweed & Co., in which Condensed Catalog No. PC 100 contains pictures and technical information and data on various types of Palmetto packings. The purpose of this Palmetto condensed catalog is to give present and prospective users a quick look at the "simple—yet complete" line of Palmetto packings. It contains information on the recommended services and on the construction and performance features of most of the Palmetto packings.

Included in the catalog are braided, twist, plaited, pelro, cutno, super-cutno, klero, plastic packing, jute, flax, palco, hydraulic duck, high pressure, and cab cock, to name a few.

The bulletin also contains an ABC application chart for Palmetto self-lubricating packings showing the services to which they may be put and the packing which may be used for the various services.

Palmetto Condensed Catalog No. PC 100 may be obtained from Greene, Tweed & Co., Bronx Blvd. at 238th St., New York 66, N. Y.

Slurry Pumps

In Bulletin 181 the Morris Machine Works, Baldwinsville, N. Y., have presented their **Type-R Slurry Pumps.** This catalog contains performance charts showing how to select a slurry pump to insure maximum life, tells how the shell is interchangeable for right or left-hand rotation, how the suction and discharge nozzles can be rotated around the axis of the pump to positions in any of the four quadrants; shows how the Type "R" has no internal studs or bolts, how the impeller is easily removed; and it describes the design of the stuffing box, and shows how the Type "R" Slurry Pump may be easily maintained at low cost. Photographs of the various parts and of applications are shown. Diagrams of right and left-hand pumps, and graphs showing recommended ranges for various types and kinds of liquids for different sizes of pumps are included. These are the Selection Charts.

Bulletin 181 on **Morris Type-R Slurry Pumps** may be obtained from the Morris Machine Works, Baldwinsville, N. Y.

PRODUCTION
FROM GLAUBER'S modern plant to the Nation's communities flows a steady stream of "Red Brass" ground key work which is unsurpassed for smooth, easy operation and long life service. Designed with a mechanically perfect taper that is free of overlap, these full opening keys and stops are permanently lubricated with Glauber's Special Valve Grease Formula which will not deteriorate even under excessive heat or cold.
Over 50 years of experience in ground key design plus new precision methods have made possible this improved Glauber's line of ground keys and stops.
Write today for quotations and estimated delivery on your specific waterworks requirements.
THE Glauber BRASS MFG. CO., KINSMAN, OHIO
Division of H. B. SALTER MFG. CO.
Marysville, Ohio
Glauber
RED BRASS

WATER REFINING
EQUIPMENT HEADQUARTERS
INDUSTRIAL—PROCESS
RAILROAD—MUNICIPAL—HOUSEHOLD

FILTERS Of All Types *and* Capacities . . . Gravity . . . Pressure

SOFTENING SYSTEMS
All Types *and* Capacities—Zeolites (*synthetic and natural*) and Lime and Soda

CHEMICAL FEEDERS (wet or dry)
Acids . . . Hypochlorites . . . Alkalies

EQUIPMENT FOR REMOVAL
Of Iron . . . Taste . . . Odors . . . . . Colors . . . Suspended Matter . . .

SWIMMING POOL EQUIPMENT
AERATORS • DE-GASIFIERS
WATER TEST SETS
RE-CARBONATORS

The AMERICAN WATER SOFTENER COMPANY
WATER REFINING EQUIPMENT HEADQUARTERS
INDUSTRIAL • PROCESS • RAILROAD • MUNICIPAL • HOUSEHOLD, ETC.
322 LEHIGH AVE., PHILA, PA.

Air Blowers

With a continuous front and back cover showing a beautiful waterfall, the Roots-Connersville Blower Corp. has issued an eight-page booklet, Bulletin 23-120-B10, titled **Air Guards the Purity of Water Supply Sources.**

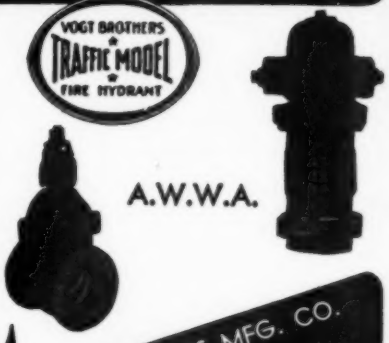
The bulletin covers various types of equipment for use in water and sewage works. The company's word, "dual-ability," is the theme developed in showing numerous rotary positive and centrifugal installations in typical sewage disposal plants.

In addition to photographs of actual installations, there are brief descriptions accompanying each indicating the capacity and pressure of the blower shown. Diversity of driving arrangements is also covered, as these R-C blowers can be driven by any type of standard drive that best suits the individual plant's requirement. Direct coupled gas engines, operating on sludge gas, are among the types of drives shown.

Also included in the book are photographs and descriptions of other applications of Roots-

WRITE FOR INFORMATION

VOGT BROTHERS TRAFFIC MODEL FIRE HYDRANT



A.W.W.A.

VOGT BROTHERS MFG. CO. Incorporated LOUISVILLE, KY.
MAIN AT 14th
VOGT
VOGT MFG. CO., Incorporated LOUISVILLE, KY.
P. O. BOX 1122

AERO-MIX

AERATOR—MIXER
A Size and Type to Fit Your Problem In Water or Sewage Treatment.

WRITE FOR INFORMATION

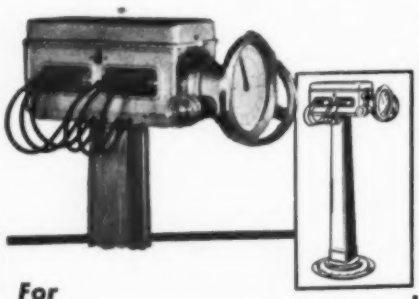
CLIMAX
High Pressure Test Plugs
for
Cast Iron & Steel Pipe

For Bell & Spigot Cast Iron Pipe. Simple operation. All sizes carried in stock.

These plugs valuable for testing steel pipe lines. A complete set of both types on your repair trucks will prove a good investment.

Write today for complete information

THE
RICHMOND
FOUNDRY & MANUFACTURING CO.
INC.
1200 Hermitage Road
RICHMOND 20 -:- VIRGINIA

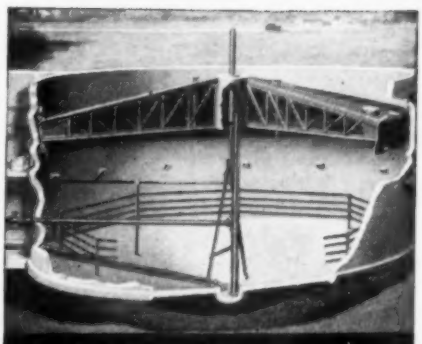


For
BALANCED PUMP OPERATION
Specify
SELECTROL

SELECTROL closely balances total pump capacity with rate of inflow at each operating level, for either rising or falling level cycle. It handles up to 18 circuits singly or in combination for any float travel up to 40 feet. A large number of circuits can be handled on limited float travel. A feature of SELECTROL is the "Lost Motion Clutch" which balances pumps of unequal capacity without "hunting". AUTOMATIC can help you with your multiple circuit problems.

Write for Bulletin S-7.

AUTOMATIC CONTROL Company
1013 University Ave., St. Paul 4, Minn.



P.F.T. Supernatant Selector

provides a positive means of selecting and removing the best supernatant liquor from digestion tanks at a slow, continuous rate, regardless of location of supernatant in tank. Vertical slotted tube of selector extends through all zones where strata of supernatant form. Effective capacity of the tank for the reduction of solids is increased. Rate of withdrawal can be controlled within fairly close limits with the P.F.T. Supernatant Gauge, Sight-Glass and Sampler. Ask for Bulletin No. 243.

P.F.T. PACIFIC FLUSH TANK CO.
4241 RAVENSWOOD AVE., CHICAGO
NEW YORK • CHARLOTTE, N. C.
SAN FRANCISCO • LOS ANGELES

RENEW
Water Meter Accuracy

Dissolve Costly Scale Quickly with
NU-COIL
Makes Meters Function Like New!
NU-COIL removes lime scale and water solids in a jiffy . . . cuts through sludge and flint-like deposits efficiently. NU-COIL is designed to protect light metals . . . precision fittings . . . rubber bushings and porcelain meter faces.
NU-COIL is mild, easy to handle . . . leaves no choking fumes.

1. Easy to Use
2. QUICK Acting
3. No Disagreeable Odor
4. Efficient
5. Economical

SKASOL CORPORATION
116 Glencoe Ave. • Webster Groves 19, Mo.
Send for FREE Descriptive Folder

Connersville equipment, such as vacuum pumps for filter service, for priming large centrifugal pumps, meters for measuring sludge gas, water meters and motors, as well as blowers for water aeration and carbonation.

Bulletin 23-120-B10 may be obtained from the Roots-Connersville Blower Corp., 900 W. Mount St., Connersville, Ind.

100 Per Cent Metering

"How a Community Is Benefited by Metering All Services" was the title of an article by Ted H. Kain, Columbia Water Company, Columbia, Pa. This article was one of the winners in the National Contest of Rockwell Manufacturing Co. last year, and is published in the March-April 1947 issue of the **Pittsburgh Empire Water Journal.** Mr. Kain's article was based on material gathered from personal experience, technical journals, information from other water companies, and common sense. The article is well worth reading.

The Pittsburgh Empire Water Journal may be obtained from Rockwell Manufacturing Company, Pittsburgh 8, Pa.

FOR BETTER
pH Control
and WATER TESTS
there is nothing like

NON-FADING GLASS COLOR STANDARDS

Pocket Comparator No. 605

Permanent reliability of Hellige Glass Color Standards, accuracy of color comparison, simplicity of the technique, and compactness of the apparatus are exclusive features of Hellige Comparators not found in any similar outfits.

WRITE FOR BULLETIN No. 602

HELLIGE
INCORPORATED
3718 NORTHERN BLVD. LONG ISLAND CITY 1, N.Y.
HEADQUARTERS FOR COLORIMETRIC APPARATUS

No caulking . . . no need to dig large bell holes . . . . large savings

Haymanite
THE PERMANENT, SELF-SEALING JOINTING COMPOUND FOR BELL AND SPIGOT CAST IRON WATER MAINS

LEAD TOO HIGH?
CUT COSTS 75%

Haymanite goes 4 times as far as lead, and, saves time, fuel and handling. Fewer tools are needed. Easily applied by any workman. Write for free, illustrated catalog.

Producers also of
M. H. Brand Caulking Lead

MICHAEL HAYMAN & CO.,
INCORPORATED
ESTABLISHED 1869
870 EAST FERRY ST.
BUFFALO, N.Y.

STEAM PLANT EQUIPMENT FOR SALE

2—250 H. P. Casey Hodges Water Tube Boilers, #32124-32125.
139 tubes—3½ x 18 ft.
Equipped with 2 new 2" blow down valves.
2—10 x 6 x 10 Boiler feed water pumps.
1—Hotwell pump—5 x 6 x 10.
1—Boiler compound pump—4½ x 3 x 2.
1—Allis Chalmers horizontal cross compound condensing Corliss pumping engine #892, made 1911. Capacity 6 M.G.P.D.—Speed 42 R.P.M.
Steam at throttle 150#—working pressure 150-175.
Piston—high side 22 x 36.
Piston—low side 46 x 36.
Water plunger—14 x 36.
Pump complete with vacuum pump and condenser.
1—Westinghouse Air Compressor #190970—size 8 x 5½ x 10.
1—85 H.P. low duty Curtiss G. E. Steam Turbine #28474. 3,860 R.P.M. with reduction gear.
1—Hot well Worthington single action pump #B253769, size 5½ x 8 x 7.
1—New Gardner Denver Steam Pump, #109295—size 6 x 5½ x 6.

To be sold where it is, as is, and to be dismantled by the purchaser within 30 days after purchase. Equipment can be inspected at any time.

Muskogee City Water Department
Municipal Building,
Muskogee Oklahoma

FEED-METERS-MIXES
CHLORINE GAS ACCURATELY

PURIFICATION FOR WATER-SEWAGE & SWIMMING POOLS

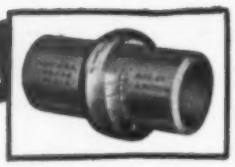
Everson SterElators Operate Manually or Semi-Automatically, Also Automatically Proportion Gas Flow to Water Flow.

Everson SterElators Utilize a 24" Water Gauge Vacuum and Visible Flow Meters, with Wide Ratio Ranges of Capacities: 10 to 1, 50 to 1, 110 to 1.

All SterElators Are Dependable, Accurate, Safe and Easy to Operate. Guaranteed to Give Complete Satisfaction.

SterElators by Everson
EVERSON MFG. CO.
233 W. Huron Street
Chicago 10, Ill., U. S. A.

WESTON



GASKET AND FORM
The Perfected Method for Making Sewer Pipe Joints of Cement

- No jute used—gasket centers spigot.
- Definite space in each joint for cement.
- Form confines cement-grout to lower portion of joint.
- Particularly advantageous in water-bearing trenches.
- Infiltration minimized.

L. A. WESTON **Adams, Mass**

REPAIR and SAVE
Water Meter Measuring Chambers
with the
MEMPHIS SLOT INSERT
of stainless steel with new bronze thrust roller.
For further information and *free* ⅝" samples
address
METER SPECIALTY CO.
1332 N. Seventh St. Memphis, Tenn.

ANTHRAFILT
Trade Mark Reg. U. S. Patent Office
A Filter Medium For All Purposes
ANTHRACITE EQUIPMENT CORP.
Anthracite Institute Building
Wilkes-Barre, Pa.
All correspondence regarding sales and engineering should be addressed to:
PALMER FILTER EQUIPMENT CO.
822 E. 8th St. Erie, Pa.
Engineers and Sales Agents

COPPERAS
(Ferrous Sulphate)
• • • •
LIQUID CHLORINE
100 lb. and 150 lb. cylinders
New York Metropolitan Area deliveries.
E. M. Sergeant Pulp and Chemical Co., Inc.
7 Dey Street, New York 7

Pumps and Water Systems

The Duro Co., a division of Hydraulic Machinery, Inc., of Dayton, manufacturers of electric pumps, residence water systems for shallow and deep wells, suction and well cylinder and ejection types, galvanized tanks, water softeners and water conditioning equipment for household and industrial application, have issued a new Catalog No. 47, titled **Duro Pumps—Water Systems.**

Included in this 20-page bulletin are the following: A guide to the selection of a Duro pump or water system, outstanding features of a shallow well pump, specifications for shallow well pump, "Vertitank" water systems specifications, specifications for "Duromatic" and fresh flow water systems, and heavy duty shallow well pumps.

Also included are outstanding features of deep well pumps and specifications for various models of these pumps, as well as the features and specifications of the "Duro-Jet" pumps and water systems.

The bulletin concludes with a list of pump and water system accessories. Shown throughout the book are illustrations of the various pieces of equipment mentioned.

These types of pumps and water systems find use not only in farms and individual homes, but also in

POSITION OPEN
City Biochemist. $400 to $500 per mo. plus $48.96 cost-of-living. Two years' practical experience directing biological laboratory or comparable experience; post-graduate training equivalent to M.A. and preferably Ph.D. in one of the sanitary sciences. Applications received until needs of service filled. Write Personnel Department, City Hall, Madison 3, Wisconsin.

FOR SALE
One, McIntosh & Seymour Diesel, type 2B-25, Engine #1909, 110 H.P., 2 cylinder, R.P.M. 275, Air injection. This unit coupled to a 3-Cyl. Gould pump size 13x16, Number 49211, Figure 1585, 1000 G.P.M. at 150 lbs.
Manhasset-Lakeville Water District
176 East Shore Rd. Great Neck, N. Y.

SURFACE WASH SYSTEMS FOR SALE
Satisfied with your present method of Filter Wash? Send for details. No obligation.
STUART-BRUMLEY CORP.
516 No. Charles St., Baltimore, Md.

BOND-O
Sulphur Joint Compound
Our BETTER BLENDING means that each batch of BOND-O comes out of our machines exactly compounded and thoroughly mixed. Cast iron pipe joints made with BOND-O show this difference. Less initial leakage from every joint made.
NORTHROP & COMPANY, INC.
50 CHURCH STREET
NEW YORK 7, N. Y.

Universal
RAIN GAGE
A versatile, low cost, precision instrument for measuring precipitation in all forms. Using interchangeable parts many different assemblies can be made up for rain or snow, heated gages, remote indicating and accumulating gages. Total cost of parts for basic Rain Gage only $4.75.
Descriptive circular sent on request
M. C. STEWART
Ashburnham Massachusetts

ALUM FOR SALE—
Satisfied with the power of your coagulant? Send for sample of Activated Alum. No obligation.
STUART-BRUMLEY CORP.
516 No. Charles St. Baltimore, Md.

STOP
JOINT LEAKAGE
WITH
CARSON CLAMPS
AND MECHANICAL JOINTS
Charcoal iron bolts for Cast Iron Pipe and Fittings.
Write for Prices.
Carson-Cadillac Co.
1221 PINSON ST. BIRMINGHAM, ALA.

small industrial plants and in water and sewage plants. In the latter they may be useful not only as a source of water supply for outlying stations, but also as a means of supplying water to bearings and Venturi tubes, measuring devices, etc., on sludge and sewage lines.

Catalog No. 47 may be obtained by writing The Duro Co., Dayton 1, Ohio.

Control Devices

The Brown Instrument Co., a division of Minneapolis-Honeywell Regulator Co., has issued Catalog No. 8302, titled **Industrial Control Devices.** This bulletin contains information on electric and pneumatic automatic control systems, and shows industrial control devices and safeguards with complete schematic diagrams, dimensional drawings and photographs of the instruments, as well as specifications, range charts, etc.

Among the electric controls are pressure, temperature and humidity, engine safety cutouts, float switches and low water cut-offs, safety shut-off valves, etc.

A copy of "Industrial Control Devices," catalog No. 8302 may be obtained by writing Brown Instrument Company, Wayne & Roberts Aves., Philadelphia 44, Pa.

Heating, Ventilating, Air Conditioning

Allis-Chalmers Products for Heating, Ventilating, Air Conditioning are portrayed and described in a twelve-page bulletin No. 25B6183. Included in the bulletin is information on Texrope V-belt drives, centrifugal pumps, motors, controls, transformers, and a-c and d-c welders.

Bulletin 25B6183 may be obtained from Allis-Chalmers Mfg. Co., Milwaukee 1, Wis.

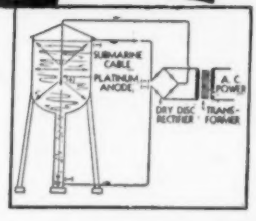
AMERICAN GAS BOILERS
STEAM AND WATER TYPES
for Digester Heating
FOR RATINGS AND DATA SEE OUR PAGE IN THE 1946 ANNUAL REFERENCE SECTION
American Radiator & Standard Sanitary Corporation, Pittsburgh 30, Pa.
AMERICAN-Standard
HEATING PLUMBING
Serving the Nations' Health and Comfort
SALES OFFICES IN PRINCIPAL CITIES

PANGO THE ACCURATE SEWAGE SAMPLER
Takes the Guesswork Out of Sewage Treatment
An accurate method of sampling tank liquids at frequent intervals is essential to effective control of sewage treatment.
PANGO is simple to use, foolproof and inexpensive. Always works, and at any level. Always obtains a true sample. Through its use, pumping and fuel costs are reduced enough to pay for the Sampler in one month.
DRAKE MANUFACTURING COMPANY
1461 Belfield Ave. Philadelphia, Pa.

for CONCRETE and STEEL!
Inertol Protection Means Lowest Cost Per Year
INERTOL COMPANY, INC. NEW YORK 5, NEW JERSEY and SAN FRANCISCO 7, CALIFORNIA

EDSON
DIAPHRAGM PUMPS
Hand Sizes 2", 2½", 3", 4"
Power Sizes 3" and 4"
Open Discharge or Force Pump
Edson Special Suction Hose
Red Seal Diaphragms
Strainers and Foot Valves
Hose Spanners—Adapters
THE EDSON CORPORATION
Main Office and Works: 49 D St. South Boston, Mass.
New York: 142 Ashland Pl., Brooklyn

RUSTA RESTOR Keeps Tanks in Continuous Service

Modern Proved Cathodic Method Provides Lasting Protection Against Rusting — Eliminates Both the Loss of Service, and Cost, of Interior Painting.
Engineered to the individual tank and water conditions Rusta Restor, the modern, cathodic method, maintains the tank in a "neutralized" state that not only prevents rusting but also removes the products of any earlier rusting. Approved and endorsed by national and state authorities. Inexpensive to install. Operation costs two mills ($0.002) per year per sq. ft. of surface protected.


RUSTA RESTOR
A DIVISION OF
THE JOHNSTON & JENNINGS COMPANY
853 ADDISON ROAD • • • CLEVELAND 14, OHIO

Consulting Engineers

SPECIALIZING IN THE FIELD OF

WATER & SEWAGE WORKS

ALBRIGHT & FRIEL, INC.

Consulting Engineers

Water, Sewage and Industrial Waste Problems — Airfields, Refuse Incinerators, Power Plants — Industrial Buildings
City Planning - Reports - Valuations

Laboratory

1528 Walnut Street, Philadelphia 2

Alvord, Burdick & Howson

Engineers

Charles B. Burdick
Louis R. Howson
Donald H. Maxwell

Water Works, Water Purification, Flood Relief, Sewerage, Sewage Disposal, Drainage, Appraisals, Power Generation

Civic Opera Building — Chicago

ARGRAVES & MORT

ENGINEERS

Sewerage and Sewage Treatment
Refuse Disposal—Industrial Wastes
Water Supply and Purification—Dams

70 COLLEGE ST. — NEW HAVEN, CONN.

Michael Baker, Jr.

The Baker Engineers

CIVIL ENGINEERS AND PLANNERS
MUNICIPAL ENGINEERS

Airport Design—Sewage Disposal Systems
Water Works Design and Operation
Consulting Services - Surveys and Maps

HOME OFFICE—ROCHESTER, PA.

W. H. & L. D. BETZ

CONSULTANTS ON ALL WATER PROBLEMS

Process, Boiler and Municipal Water • Waste and Sewage Treatment • Consultation • Design • Analysis

PHILADELPHIA 24, PENNA.

BLACK & VEATCH

Consulting Engineers

4706 Broadway, Kansas City 2, Mo.

Water Supply Purification and Distribution; Electric Lighting and Power Generation, Transmission and Distribution; Sewerage and Sewage Disposal; Valuations, Special Investigations and Reports.

BOGERT-CHILDS ENGINEERING ASSOCIATES

CONSULTING ENGINEERS

Clinton L. Bogert — John M. M. Greiz
Howard J. Carlock — Fred S. Childs

Water Supply and Purification
Sewerage and Sewage Treatment
Flood Control and Drainage
Refuse Disposal
City Planning—Investigations—Reports

624 Madison Avenue, New York 22, N. Y.

BOWE, ALBERTSON & ASSOCIATES

Engineers

Sewerage—Sewage Treatment
Water Supply—Purification
Refuse Disposal—Analyses
Municipal—Industrial Projects
Valuations—Reports—Designs

110 William St. New York 7, N. Y.

Buck, Seifert and Jost

Consulting Engineers

(Formerly Nicholas S. Hill Associates)

Water Supply, Sewage Disposal, Hydraulic Developments, Reports, Investigations, Valuations, Rates, Design Construction Operation. Management, Chemical and Biological Laboratories

112 East 19th St. — New York

BURNS & McDONNELL ENGINEERING COMPANY

Consulting Engineers 50th Year

Water Works, Light & Power, Sewerage, Rate Investigations, Reports, Designs, Appraisals.

P.O. Box 7088, Country Club Sta.; Office, 95th and Troost Avenue, Kansas City 2, Missouri

Camp, Dresser & McKee

Consulting Engineers

6 Beacon Street, Boston 8, Mass.

Water Works and Water Treatment; Sewerage and Sewage Treatment; Municipal and Industrial Wastes; Investigations and Reports; Design and Supervision; Research and Development; Flood Control.

The Chester Engineers

Water Supply and Purification, Sewerage and Sewage Treatment, Power Development and Applications, Investigations and Reports, Valuations and Rates.

210 E. Park Way at Sandusky, Pittsburgh 12, Pa.

DE LEUW, CATHER & COMPANY

Water Supply — Sewerage
Railroads — Highways
Grade Separations—Bridges—Subways
Local Transportation

Investigations — Reports — Appraisals
Plans and Supervision of Construction

20 North Wacker Drive — Chicago

FAY, SPOFFORD & THORNDIKE

Engineers

Charles M. Spofford
John Ayer — Carroll A. Farwell
Bion A. Bowman — Ralph W. Horne

Water Supply and Distribution — Drainage
Sewerage and Sewage Treatment—Airports
Investigations and Reports
Designs — Valuations
Supervision of Construction

Boston — New York

GANNETT FLEMING CORDDRY AND CARPENTER, INC.

Harrisburg, Pa. — New York, N. Y.

ENGINEERS

Water Works, Sewage, Industrial Wastes & Garbage Disposal—Roads, Airports, Bridges & Flood Control. Town Planning, Appraisals, Investigations & Reports.

GILBERT ASSOCIATES, INC.

Engineers and Consultants

Water Supply and Purification
Sewage Treatment and Industrial Waste
Chemical Laboratory Service

New York — READING — Washington

I. M. Glace

Consulting Sanitary Engineer

WATER SUPPLY AND PURIFICATION
SEWERAGE AND SEWAGE TREATMENT

Specializing in Water Quality Problems

Telephone 6-0407 — 1061 North Front St. Harrisburg, Pa.

WILLIAM A. GOFF

Consulting Engineer

Water, Sewerage, Refuse Incinerators, Industrial Buildings, Power Plants, Investigations Reports Design Supervision of Construction Valuations

Broad St. Station Bldg., Philadelphia 3, Pa.

GREELEY AND HANSEN

Engineers

Samuel A. Greeley — Paul Hansen (1920-1944)
Paul E. Langdon — Kenneth V. Hill
Thomas M. Niles — Samuel M. Clarke

Water Supply, Water Purification
Sewerage, Sewage Treatment
Flood Control, Drainage, Refuse Disposal

220 S. State Street, Chicago 4

Havens and Emerson

W. L. Havens — C. A. Emerson
A. A. Burger — F. C. Tolles — F. W. Jones

Consulting Engineers

Water, Sewage, Garbage, Industrial Wastes, Valuations — Laboratories

Leader Building, Cleveland 14 — Woolworth Bldg. New York 7

Hayden, Harding & Buchanan

Consulting Engineers

John L. Hayden
John H. Harding — Oscar J. Campia

Waterworks, Sewerage, Civil, Mechanical, Electrical, Structural

826 Park Square Building, Boston, Mass.

Charles Haydock
Consulting Engineer

Water Works and Sanitation, Industrial Wastes, Design, Construction, Operation and Management. Reports and Valuations.

COMMERCIAL TRUST BUILDING
PHILADELPHIA 2

JONES & HENRY
Formerly H. P. JONES & CO.

Harvey P. Jones **Thomas B. Henry**

Consulting Engineers

Reports, Designs, Supervision, Valuation
Water Supply — Refuse Disposal
Water Purification — Industrial Wastes
Sewerage — Flood Control
Sewage Treatment — Drainage

Security Bldg. **Toledo 4, Ohio**

ENGINEERING OFFICE OF CLYDE C. KENNEDY
COMPLETE ENGINEERING SERVICE
For More Than a Quarter Century

Investigations, Reports, Design, Supervision of Construction and Operation

Water Supply, Water Conditioning, Sewerage, Sewage and Industrial Waste Treatment

CHEMICAL and BIOLOGICAL LABORATORY
604 Mission Street **San Francisco, 5**

Morris Knowles, Inc.
Engineers

Water Supply and Purification, Sewerage and Sewage Disposal, Valuations, Laboratory, City Planning

1312 Park Building, Pittsburgh, Pa.

WM. S. LOZIER CO.

Sewerage, Sewage Disposal, Water Supply, Water Purification, Refuse Disposal

Consulting Engineers

10 Gibbs Street **Rochester 4, N. Y.**

Metcalf & Eddy
Engineers

Water, Sewage, Drainage, Refuse and Industrial Waste Problems
Airfields — Valuations
Laboratory

Statler Building, Boston

MOORE & OWEN
ENGINEERS

WATER, SEWAGE, INCINERATION
REFUSE DISPOSAL, AIRFIELDS
COMPLETE WATER & SEWAGE
LABORATORIES, INDUSTRIAL WASTES

1456 N. DELAWARE ST.
INDIANAPOLIS 2, IND.

Nussbaumer and Clarke
Newell L. Nussbaumer **Irving Clarke**

Water Supply and Treatment
Sewerage & Sewage Disposal
Garbage Incineration
Town Planning

327 Franklin St. **Buffalo, N. Y.**

LEE T. PURCELL
Consulting Engineer

Water Supply and Purification
Sewerage and Sewage Disposal
Industrial Wastes
Design, Supervision of Construction and Operation
Complete Laboratory Services

1 LEE PLACE
PATERSON 1, NEW JERSEY

Parsons, Brinckerhoff, Hogan & Macdonald
Engineers

Traffic Reports — Valuations — Harbor Works
Power Developments — Industrial Buildings
Bridges — Tunnels — Subways — Foundations
Dams — Water Works — Sewerage

142 Maiden Lane, New York 7
Calle Sur 17 No. 27, Caracas, Venezuela
Edificio Suarez Costa, Bogota, Colombia

Malcolm Pirnie Engineers
Civil & Sanitary Engineers

Malcolm Pirnie **Ernest W. Whitlock**
Robert W. Sawyer **G. G. Werner, Jr.**
Richard Hazen

Investigations, Reports, Plans
Supervision of Construction and Operations
Appraisals and Rates

25 West 43rd St., New York 18, N. Y.

The Pitometer Company
Engineers

Water Waste Surveys, Trunk Main Surveys, Water Distribution Studies
Penstock Gaugings
New York, 40 Church St.

ROBERT T. REGESTER
Consulting Engineer

Water Works — Sewage Treatment
Hydraulic Structures — Utilities

Baltimore Life Bldg. **Baltimore 1, Md.**

Thomas M. Riddick
Consulting Engineer and Chemist

Municipal and Industrial Water Purification, Sewage Treatment, Plant Supervision, Stream Pollution Investigations, Chemical and Bacteriological Analyses.

369 East 149th Street
New York 55, N. Y.

ROBERT AND COMPANY
INCORPORATED
Architects and Engineers

WASHINGTON • ATLANTA • NEW YORK

WATER SUPPLY — INCINERATORS
SEWAGE DISPOSAL — POWER PLANTS

MR. CONSULTING ENGINEER

Are you interested in both
WATER & SEWAGE?
If so there is no better place for your professional card than in this dual interest magazine

WATER & SEWAGE WORKS

RUSSELL & AXON
Consulting Engineers

Geo. S. Russell — F. E. Wenger
Joe Williamson, Jr.

Water Works, Sewerage, Sewage Disposal, Power Plants, Appraisals

6635 Delmar Blvd. **Municipal Airport**
St. Louis 5, Mo. **Daytona Beach, Fla.**

Lester L. Sargent
Registered Patent Attorney

Elevent Fifteen K Street, N.W.
P. O. Box 3156
Washington, D. C.

J. E. Sirrine & Company
Engineers

Water Supply & Purification
Sewage & Industrial Waste Disposal
Stream Pollution Reports
Utilities, Analyses

Greenville **South Carolina**

Benjamin L. Smith & Associates
Engineers
(Formerly Whitman and Smith)

Investigations — Reports
Designs — Supervision — Valuations
Municipal Engineering and Public Utilities

11 North Pearl Street
Albany 7, New York

STANLEY ENGINEERING COMPANY *Consulting Engineers*

Water Works — Sewerage
Electric Power — Flood Control
Rate Studies—Valuations—Industrial
Airports . . . Municipal Buildings

Hershey Bldg., Muscatine, Ia.

PHILIP B. STREANDER AND AFFILIATES
CONSULTING SANITARY ENGINEERS
Damon and Foster, Engrs.
Sharon Hill, Del. Co., Pa.
Cleverdon, Varney & Pike, Engrs.
120 Tremont St., Boston 8, Mass.

Water Supply, Treatment, Distribution
Trade Wastes, Refuse Disposal
Sewerage, Sewage Treatment
Plans, Supervision, Reports

Weston & Sampson

Water Supply, Water Purification, Sewerage, Sewage and Industrial Waste Treatment, Corrosion Control, Laboratory Service, Supervision, Valuations

14 Beacon St. **Boston, Mass.**

Whitman & Howard
Engineers (Est. 1869—Inc. 1924)

Channing Howard — Paul F. Howard
Edwin M. Howard — C. Roger Pearson

Water Supply, Water Purification, Sewerage, Sewage Disposal, Water Front Improvements and all Municipal and Industrial Development Problems, Investigations, Reports, Designs, Supervision, Valuations.

89 Broad St., Boston, Mass.

WHITMAN, REQUARDT AND ASSOCIATES
Engineers — Consultants

Civil—Sanitary—Structural—Mechanical—Electrical. Reports, Plans, Supervision, Appraisals

1304 St. Paul Street
Baltimore 2, Maryland

THIS SPACE IS AVAILABLE

At reasonable cost to Consulting Engineers interested in reaching both Water and Sewage Works Authorities.

Rates upon request

WATER & SEWAGE WORKS
22 W. Maple St., Chicago
155 E. 44th St., New York

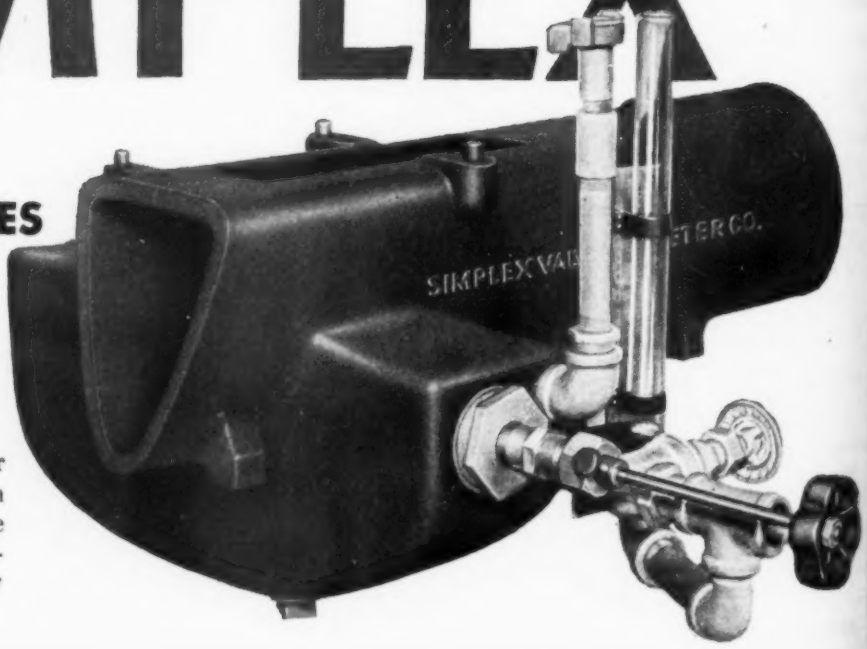
For open flow of water, sewage, industrial liquids . . .

SIMPLEX TYPE S-PARABOLIC FLUME METERS HAVE ALL THESE GREAT ADVANTAGES!

1. Compact cast iron measuring section—ready to place in the line.
2. Self-scouring design permitting passage of sediment or solids.
3. No pockets or grooves in measuring section to clog up or facilitate accumulation of matter.
4. No straight section of pipe on exact grade required upstream of flume casting.
5. Can be attached to larger pipe sizes by eccentric reducer thereby saving installation costs.
6. Operates under extreme low head and low flow conditions.
7. Small head loss—requires very little free fall at outlet.
8. Generous capacity to handle high—as well as low flows.
9. Ability to measure over long flow range—from maximum to 5% of maximum.
10. Mechanical or electrical transmission from flume to meter with indoor or outdoor installation as desired.
11. Available in sizes 6" diameter to 36" diameter inclusive.

SIMPLEX

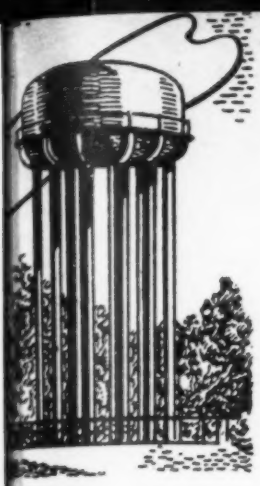
TYPE-S PARABOLIC FLUMES



Send for your copy of Bulletin 210 — complete operation, installation, capacity data

SIMPLEX VALVE & METER COMPANY

6743 UPLAND STREET, PHILADELPHIA 42, PA.



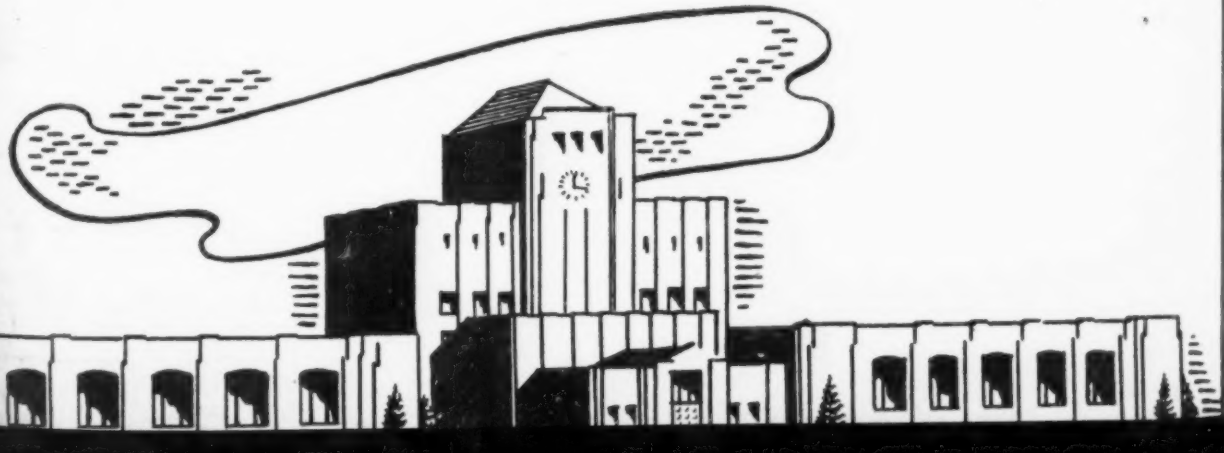
PART 1

WATER SUPPLY

WATER & SEWAGE WORKS

REFERENCE & DATA SECTION

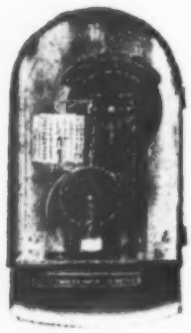
1947



SIMPLEX VALVE & METER COMPANY

6743 UPLAND STREET, PHILADELPHIA 42, PENNSYLVANIA

SIMPLEX stands for LEADERSHIP in WATER WORKS & SEWAGE EQUIPMENT



TYPE MO METER

Indicates, records and totalizes fluid flow rates. Consistent high accuracy over wide flow range (up to 43 to 1); extreme sensitivity to every change in flow; simplicity of design, trouble-free operation, minimum maintenance cost. Evenly graduated, direct reading flow scale and chart. Floor stand, wall bracket or Panel Board mounting.

BULLETIN 300

TYPE S PARABOLIC FLUME

Measures flow of water, sewage and other liquids under gravity flow conditions. Used with water float operated instrument, flow ranges of 100% to 5% capacity are accurately indicated, recorded and totalized. Operates with small loss of head. Available in sizes 6" to 36", inclusive.

BULLETIN 210

AIR RELEASE VALVE

Automatically vents air obstructions that might otherwise cause operating loss or damage to pipe lines and pumps. Dependable in service. Simple construction—one lever movement operates a tight seating needle valve, actuated by a heavy glass ball float. Types for pressures up to 1250 lbs. per sq. in. — tested to several times the service working pressure.

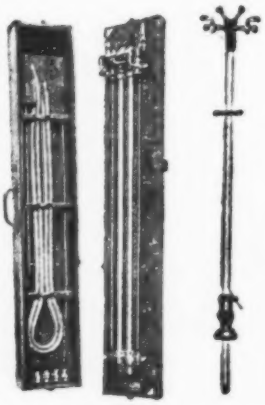
BULLETIN 140

TYPE MS FLOW RATE METER

Accurately indicates, records and totalizes flow rate. Bell-shaped float automatically extracts the square root of the law of flow and makes possible the direct reading chart—evenly graduated from 0 to maximum. The arm of the recording pen connects directly with the float for inevitable accuracy of transcription and sensitivity to flow change.

BULLETIN 350

PITOT EQUIPMENT



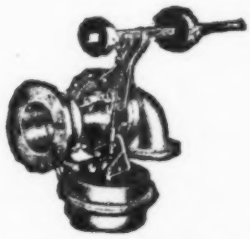
Check the operating efficiency of distribution systems, pumps, meters. Panel board, portable, or stationary Recorders, manometers, and pitot tube types of equipment for accurate surveys—at low cost and with small expense — effect definite savings in operating loss.

BULLETIN 50

AIR INLET VALVE

Eliminates the possibility of collapse of pipe line walls due to sudden drop in pressure in gravity flow line. The non-collapsible float is buoyed by the water in the line until a condition arises which tends to create a vacuum—then the buoying effect of the water is lost, the float drops from its seat, to admit air and destroy the vacuum.

BULLETIN 125



RATE OF FLOW CONTROLLERS

For gravity or pressure Filters, Clearwells, etc. A direct acting, balanced valve type controller, operated by a Venturi tube located in the effluent line. Lowest obtainable head losses when wide open; highest degree of accuracy without compensating mechanisms; largest possible ratio from maximum to minimum rates with any given size of unit; no electrical mechanisms used in operation. The controller starts quickly from a wide open position and takes the set rate in less than 15 seconds. Adapted to various types of clearwell control.

BULLETIN 250

GAUGES

Indicating, recording, and/or totalizing gauges, strictly proportional to the Rate of Flow or Loss of Head. Mercury Float or Water Operated. Types for gauging Loss of Head, Rate of Flow, Depth, Elevation, Sand Expansion, etc. All Simplex Gauges are designed for accuracy, visibility, accessibility of moving parts, and reliability in service.

BULLETIN 170

MO & MS METERS • CONTROLLERS • GAUGES • SAND EXPANSION INDICATORS • AIR RELEASE VALVES • AIR & VACUUM VALVES • PITOT EQUIPMENT • SUMMATORS • PRIMARY DEVICES (VENTURI TUBES, PITOT TUBES, ORIFICES, NOZZLES, WEIRS AND FLUMES)

"next to knowing - - - - is knowing where to find knowledge"

Foreword

We take especial pride, as publishers, in presenting this volume—

The 1947 Reference and Data Number of

WATER & SEWAGE WORKS

Prepared by the Editor and Dr. George E. Symons, as Managing Editor, with the aid of John C. Black during final production, this section presents the equivalent of a data handbook for designing engineers, managers, and operators of water and sewage works.

The information contained herein has been carefully selected from past issues of WATER WORKS AND SEWERAGE (now WATER & SEWAGE WORKS) and other sources named in the text. In addition, considerable effort has been made to present the most economical and modern methods, and the latest tables and charts useful to water and sewage works operators and designers.

Even though supplied to subscribers at no charge beyond the regular subscription fee, the same conscientious work has been put into the preparation of this Reference Section as would be expected in a book devoted exclusively to the same type of material and published separately.

* * *

Note

In the past we have repeated useful basic data, tables, graphs, etc.—from year to year, chiefly for the benefit of new subscribers; certain other matter was repeated in alternate years; and new material was, of course, added. Thus the subscriber who kept two consecutive Reference and Data issues on file had all of the most important reference material published by WATER WORKS AND SEWERAGE (now WATER & SEWAGE WORKS).

None of the material contained in the 1946 issue is repeated in this issue. Instead, the new material is being augmented with certain basic material selected from the 1945 and earlier issues, with the intent of best serving all of our readers—especially the newer readers.

Nevertheless, in order to have a complete Reference and Data file it will be necessary for the readers to have available not only the current issue but also issues of at least the two years preceding this issue. Several articles published since 1941 have not been repeated within the last three years. Therefore for the convenience of the user a consolidated seven year index is being incorporated in this issue.

L. H. Enslow

Editor.

INDEX

FOR THE INDEX TO THE REFERENCE AND DATA MATERIAL, AND THE INDEX TO ADVERTISERS, SEE THE REAR OF THIS SECTION

CLASSIFIED INDEX of PRODUCTS

ABRASIVES

Carborundum Co., Niagara Falls, N. Y.

ACID, SULPHURIC AND HYDROCHLORIC

General Chemical Co., 40 Rector St., New York 6, N. Y.
Hooker Electrochemical Co., Buffalo Ave. and Ward St., Niagara Falls, N. Y.
Niagara Alkali Co., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia 7, Pa

ACTIVATED AND BLACK ALUM

Activated Alum Corp., Curtis Bay, Baltimore, Md.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

ACTIVATED CARBON

Darco Corporation, 60 E. 42nd St., New York City 17.
Industrial Chemical Sales Division, West Virginia Pulp & Paper Co., 230 Park Ave., New York City 17.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

AERATION APPARATUS

Allis-Chalmers, Milwaukee 1, Wis.
American Water Softener Co., Philadelphia, Pa.
American Well Works, Aurora, Ill.
Carborundum Co., Perth Amboy, N. J.
Ralph B. Carter Co., 53 Park Place, New York City.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
F. B. Leopold Co., Inc., 422 First Ave., Pittsburgh, Pa.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Liquid Conditioning Corp., Linden, N. J.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Vogt Mfg. Co., Louisville, Ky.
Walker Process Equip., Inc., Aurora, Ill.
Yeomans Brothers Co., 1433 N. Dayton St., Chicago 22, Ill.

AGITATORS

American Water Softener Co., Philadelphia 33, Pa.
American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2336 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
General American Process Equipment, 420 Lexington Ave., New York 17, N. Y.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
F. B. Leopold Co., Inc., 422 First Ave., Pittsburgh, Pa.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Nooter, John, Boiler Works Co., 1410 S. 2nd St., St. Louis 4, Mo.
Omega Mach. Co., Inc., 9 Codding St., Providence 1, R. I.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Roberts Filter Mfg. Co., Darby, Pa.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Vogt Mfg. Co., Louisville, Ky.
Walker Process Equip., Inc., Aurora, Ill.
Yeomans Brothers Co., 1433 N. Dayton St., Chicago 22, Ill.

AIR BLOWERS

(See Blowers, Air)

AIR COMPRESSORS

(See Compressors, Air)

AIR RELIEF VALVES

Valve and Primer Corp., Chicago 2, Ill.

ALTERNATORS, ELECTRIC

Allis-Chalmers Mfg. Co., Milwaukee 1, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Westinghouse Electric & Mfg. Co., P. O. Box 868, Pittsburgh 30, Pa.
Yeomans Brothers Co., 1433 N. Dayton St., Chicago 22, Ill.

ALTERNATORS, MECHANICAL

Chicago Pump Co., 2336 Wolfram St., Chicago 18, Ill.

ALUM, AMMONIA

General Chemical Co., 40 Rector St., New York 6, N. Y.
Innis-Speiden & Co., 117 Liberty St., New York City.

ALUM, BLACK

(See Black Alum)

ALUM, FILTER

(See Filter Alum)

AMMONIA, ANHYDROUS & AQUA

General Chemical Co., 40 Rector St., New York 6, N. Y.
Mathieson Alkali Wks., Inc., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia 7, Pa.
E. M. Sergeant Pulp & Chemical Co., Inc., 7 Dey St., New York 7, N. Y.

AMMONIATORS

Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Milton Roy Co., Chestnut Hill, Philadelphia 18, Pa.
Omega Mach. Co., Inc., 9 Codding St., Providence 1, R. I.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Inc., Newark, N. J.

ANTHRAFILT

Anthracite Equipment Corp., 101 Park Ave., New York City.

AQUAPHONES

Northrop & Co., Inc., Spring Valley, N. Y.

ARRESTERS, FLAME

Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.
Vapor Recovery Systems, 2820 N. Alameda St., Compton, Calif.

ASBESTOS-CEMENT PIPE

Johns-Manville Co., 22 E. 40th St., New York City.

ASH AND COAL HANDLING MACHINERY

Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Dracco Corp., Cleveland, Ohio.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 300 W. Pershing Rd., Chicago 9, Ill.

BAR SCREENS

(See Screens, Sewage)

BINS, STORAGE

Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Chicago Bridge & Iron Company, 2198 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
General American Process Equipment, 420 Lexington Ave., New York 17, N. Y.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Nooter, John, Boiler Works Co., 1410 S. 2nd St., St. Louis 4, Mo.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Stacey Bros. Gas Construction Co., 5535 Vine St., Cincinnati 16, Ohio.

BITUMINOUS COATINGS AND LININGS

W. A. Briggs Bitumen Co., 3303 Richmond St., Philadelphia 34, Pa.
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Walles Dove-Hermiston, Westfield, N. J.

BLACK ALUM

Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

BLEACHING POWDER

(See Calcium Hypochlorite)

BLOWERS, AIR, GAS (Centrifugal and Rotary)

Allis-Chalmers Mfg. Co., Milwaukee 1, Wis.
De Laval Steam Turbine Co., Trenton, N. J.
Dresser Industries, Inc., Cleveland 13, Ohio.
General Electric Co., Schenectady, N. Y.
Roots-Connersville Blower Corp., Connersville, Ind.

BLOWERS (Gasoline Engine Driven Portable)

Homelite Corporation, Port Chester, N. Y.

BOILER FEEDWATER TREATMENT AND EQUIPMENT

Allis-Chalmers Mfg. Co., Milwaukee 1, Wis.
American Water Softener Co., Philadelphia 33, Pa.
American Well Works, Aurora, Ill.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Belco Ind. Equip. Div., 50 Iowa Ave., Paterson 3, N. J.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Everson Mfg. Co., 214 W. Huron, Chicago, Ill.
The Foxboro Co., Foxboro, Mass.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
La Motte Chem. Co., Towson 4, Md.
Link-Belt Co., 301 W. Pershing Rd., Chicago 9, Ill.
Liquid Conditioning Corp., Linden, N. J.
McAlear Mfg. Co., 1949 S. Western Ave., Chicago 8, Ill.
Milton Roy Co., Chestnut Hill, Philadelphia 18, Pa.
Omega Machine Co., 9 Codding St., Providence 1, R. I.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Penn.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
W. A. Taylor & Co., 7300 York Road, Baltimore, Md.
Walker Process Equip., Inc., Aurora, Ill.
Worthington Pump & Machinery Corp., Harrison, New Jersey.
Zeolite Chemical Co., 140 Cedar St., New York 6, N. Y.

BOILERS, GAS
American Radiator & Standard Sanitary Corp., Bessemer Bldg., Pittsburgh 30, Pa.

BOOKS, TECHNICAL
John Wiley & Sons, Inc., 440 4th Ave., New York 16, N. Y.

BOXES, VALVE AND METER
(See Valve Boxes; Meter Boxes)

BRASS GOODS
(See also Pipe, Brass)
American Brass Co., Waterbury, Conn.
Hays Mfg. Co., Erie, Pa.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., Spring Valley, N. Y.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.

BREECHINGS, STEEL
Chicago Bridge & Iron Company, 2198 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Dresser Industries, Inc., Cleveland 13, Ohio.
Nooter, John, Boiler Works Co., 1410 S. 2nd St., St. Louis 4, Mo.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Stacey Bros. Gas Construction Co., 5535 Vine St., Cincinnati 16, Ohio.

BUCKETS, SEWER
Champion Corp., Hammond, Ind.

BUFFER SOLUTIONS & MIXTURES
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
La Motte Chemical Co., Towson 4, Md.
W. A. Taylor & Co., 7300 York Rd., Baltimore, Md.

BUTTERFLY VALVES
(See Valves, Butterfly)

CALCIUM HYPOCHLORITE
Innis, Speiden & Co., 117 Liberty St., New York City.
John Wiley Jones Co., 124 Hardwood Ave., Caledonia, N. Y.
Mathieson Alkali Wks., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia 7, Pa.
Pittsburgh Plate Glass Co., Columbia Chemical Division, Grant Bldg., Pittsburgh 19, Pa.
E. M. Sergeant Pulp & Chemical Co., Inc., 7 Dey St., New York 7, N. Y.
Wood and Preuit, 1740 K St., N.W., Washington, D. C.

CALGON
(See Corrosion Suppression and Water Stabilization)

CALKING MACHINES & TOOLS
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.

CARBON-ACTIVATED
(See Activated Carbon)

CARBONATORS (Recarbonation).
Carborundum Co., Perth Amboy, N. J.
Dorr Co., 570 Lexington Ave., New York City.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago, Ill.
F. B. Leopold Co., Inc., 422 First Ave., Pittsburgh, Pa.
Liquid Conditioning Corp., Linden, N. J.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Vogt Mfg. Co., Louisville, Ky.

CASTINGS, IRON, STEEL, ALLOY STEEL, ETC.
Central Foundry Co., 386 Fourth Ave., New York, N. Y.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Climax Engineering Co., Clinton, Iowa.
Eimco Corp., P. O. Box 300, Salt Lake City, Utah.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hunt, Rodney, Machine Co., Orange, Mass.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
M & H Valve & Fittings Co., Anniston, Ala.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Corp., 11 Broadway, New York City.

CAST IRON PIPE
(See Pipe)

CATCH BASIN CLEANERS
Champion Corp., Hammond, Ind.

CATHODIC PROTECTIVE SYSTEMS
Electro Rust-Proofing Co., 1026 Wayne Ave., Dayton, Ohio.
Federal Telephone and Radio Corp., Newark 1, N. J.
Johnston & Jennings Co., Rusta Restor Div., 877 Addison Rd., Cleveland, Ohio.
Westinghouse Electric & Mfg. Co., P. O. Box 868, Pittsburgh 30, Pa.

CAUSTIC SODA
Diamond Alkali Co., Pittsburgh, Pa.
Hooker Electrochemical Co., Buffalo Ave. and Ward St., Niagara Falls, N. Y.
Innis-Speiden & Co., 117 Liberty St., New York City.
Mathieson Alkali Wks., 60 E. 42nd St., New York City.
Niagara Alkali Co., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia 7, Pa.
Pittsburgh Plate Glass Co., Columbia Chemical Division, 30 Rockefeller Plaza, New York City.
E. M. Sergeant Pulp & Chemical Co., Inc., Empire State Bldg., New York 1, N. Y.
Solvay Sales Corp., 40 Rector St., New York City.

CEMENT, ASBESTOS PIPE
Johns-Manville, 22 E. 40th St., New York City.

CEMENT GUN
Cement Gun Co., Allentown, Pa.

CEMENT PIPE
(See Pipe, Concrete)

CEMENT LINED PIPE
(See Pipe)

CEMENT LINING OF PIPE
Centriline Corp., 140 Cedar St., New York City.
Tate Pipe Linings, Inc., Andover, Mass.

CEMENTS, ACID PROOF
Atlas Mineral Prod. Co., Mertztown, Pa.
Northrup & Co., Inc., 50 Church St., New York 7, N. Y.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.

CEMENTS, REFRACTORY
Carborundum Co., Perth Amboy, N. J.
Johns-Manville, 22 E. 40th St., New York City.

CEMENTS, SEWER PIPE
Atlas Mineral Prod. Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.

CEMENTS, WATER MAINS
Atlas Mineral Prod. Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Leadite Co., Girard Trust Bldg., Philadelphia, Pa.
Michael Hayman & Co., 870 E. Ferry St., Buffalo, N. Y.
Northrup & Co., Inc., 50 Church St., New York 7, N. Y.

CHAINS (Elevating, Conveying & Power Transmission)
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.

CHEMICAL, CONVEYING EQUIPMENT
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Dracco Corp., Cleveland, Ohio.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.

CHEMICAL FEEDING & PROPORTIONING EQUIPMENT
American Water Softener Co., Philadelphia 33, Pa.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago, Ill.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
The Foxboro Co., Foxboro, Mass.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
F. B. Leopold, 422 First Ave., Pittsburgh, Pa.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Liquid Conditioning Corp., Linden, N. J.
Milton Roy Co., Chestnut Hill, Philadelphia 18, Pa.
Nooter, John, Boiler Works Co., 1410 S. 2nd St., St. Louis 4, Mo.
Omega Machine Co., 9 Codding St., Providence 1, R. I.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., Sixth & Byrd, Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
Wallace & Tiernan Co., Inc., Newark 1, N. J.

CHLORIDE OF LIME (Chlorinated Lime)
(See Calcium Hypochlorite)

CHLORINATORS
(See also Hypochlorinators)
Chem-Feeds, Inc., 77 Reservoir Ave., Providence, R. I.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Lapp Insulator Co., Le Roy, N. Y.
Omega Machine Co., 9 Codding St., Providence 1, R. I.
Phipps & Bird, Inc., Sixth & Byrd, St., Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Inc., Newark, N. J.

CHLORINE DIOXIDE
(See Sodium Chlorite)

CHLORINE, LIQUID
Diamond Alkali Co., Pittsburgh, Pa.
Hooker Electrochemical Co., Buffalo Ave. and Ward St., Niagara Falls, N. Y.
John Wiley Jones Co., 124 Hardwood Ave., Caledonia, N. Y.
Mathieson Alkali Wks., 60 E. 42nd St., New York City.
Niagara Alkali Co., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia 7, Pa.
Pittsburgh Plate Glass Co., Columbia Chemical Division, Grant Bldg., Pittsburgh 19, Pa.
E. M. Sergeant Pulp & Chemical Co., Inc., 7 Dey St., New York 7, N. Y.
Solvay Sales Corp., 40 Rector St., New York.

CHLORINE CONTROL EQUIPMENT
(See Residual Chlorine Control)

CHUTES, COAL, ETC.
Chicago Bridge & Iron Company, 2198 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 300 W. Pershing Rd., Chicago 9, Ill.
Nooter, John, Boiler Works Co., 1410 S. 2nd St., St. Louis 4, Mo.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

CLAMPS AND SLEEVES, PIPE
Amer. Cast Iron Pipe Co., Birmingham, Ala.
Carson-Cadillac Corp., Birmingham, Ala.
Dresser Mfg. Co., Bradford, Pa.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., Spring Valley, N. Y.
Rensselaer Valve Co., Troy, N. Y.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.

CLAMPS, BELL JOINT
Carson-Cadillac Corp., Birmingham, Ala.
Dresser Mfg. Div., Bradford, Pa.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Northrop & Co., Inc., Spring Valley, N. Y.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

CLAMPS, PIPE REPAIR
Carson-Cadillac Corp., Birmingham, Ala.
Dresser Mfg. Div., Bradford, Pa.
Northrop & Co., Inc., Spring Valley, N. Y.

CLARIFIERS, SEWAGE AND WATER
American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Hardinge Co., Inc., York, Pa.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Walker Process Equip., Inc., Aurora, Ill.
Yeomans Brothers Co., 1433 N. Dayton St., Chicago 22, Ill.

CLAY PIPE
(See Vitrified Clay Pipe and Products)

CLEANING COMPOUNDS
Oakite Products Corp., 73 Thames St., New York 6, N. Y.

CLEANING SEWAGE MAINS
(See Sewer Cleaning Equipment and Service)

CLEANING WATER MAINS
Flexible Underground Pipe Cleaning Co., 9059 Venice Blvd., Los Angeles, Calif.
National Water Main Cleaning Co., 30 Church St., New York City.
Tate Pipe Linings, Inc., Andover, Mass.

CLOROBEN
Cloroben Corp., Jersey City, N. J.

COAL & ASHES HANDLING MACHINERY
(See Ash & Coal Handling Machy.)

COATINGS, ACID & ALKALI-PROOF FOR CONCRETE, STEEL AND WOOD
Atlas Mineral Products Co., Mertztown, Pa.
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago, Ill.
General Paint Corp., 8091 Mayfield Rd., Cleveland, Ohio.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.
Philadelphia Quartz Co., Philadelphia, Pa.

COATINGS AND LININGS
(See Bituminous Coatings and Linings)

COCKS (Curb, Meter, Corporation, Etc.)
American Car & Fdy. Co., 30 Church St., New York 8, N. Y.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Ford Meter Box Co., Wabash, Ind.
Hays Mfg. Co., Erie, Pa.
Mueller Co., Decatur, Ill.
Merco Nordstrom Valve Co., Lexington Ave., Pittsburgh, Pa.
Northrop & Co., Inc., Spring Valley, N. Y.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.

COLLECTORS (Sludge)
(See Sludge Collectors)

COMBUSTION INDICATORS AND RECORDERS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Permutit Co., 330 W. 42nd St., York 18, N. Y.

COMMINUTORS
(See Grinders also)
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.

COMPARATORS
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
LaMotte Chem. Co., Towson 4, Md.
Lapp Insulator Co., Leroy, N. Y.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
W. A. Taylor & Co., 7300 York Road, Baltimore, Md.
Wallace & Tiernan Co., Inc., Newark, N. J.

COMPOUNDS, SEWER JOINT
Atlas Mineral Prod. Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Michael Hayman & Co., 870 E. Ferry St., Buffalo, N. Y.
Leadite Co., Girard Trust Co. Bldg., Philadelphia 2, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Servicised Products Corp., 6051 W. 65th St., Chicago, Ill.

COMPRESSORS, AIR
Allis-Chalmers Mfg. Co., Milwaukee 1, Wis.
Clayton Mfg. Co., Alhambra, Calif.
Cooper-Bessemer Corp., Mount Vernon, Ohio.
Davey Compressor Co., Kent, Ohio
De Laval Steam Turbine Co., Trenton, N. J.
Dresser Industries, Inc., Cleveland 13, Ohio.
Gardner-Denver Co., Quincy, Ill.
Jaeger Machine Co., 716 Dublin Ave., Columbus, Ohio.
Le Roi Co., 1706 S. 68th St., Milwaukee 14, Wis.
Northrop & Co., Inc., Spring Valley, N. Y.
Roots-Connersville Blower Corp., Connersville, Ind.
Worthington Pump & Machinery Corp., Harrison, New Jersey.
Yeomans Bros. Co., 1433 N. Dayton St., Chicago 22, Ill.

CONCRETE BREAKERS
Gardner-Denver Co., Quincy, Ill.
Northrop & Co., Inc., Spring Valley, N. Y.

CONCRETE CONTROL
Master Builders Corp., Cleveland, Ohio.

CONCRETE HARDENER
Diamond Alkali Co., Pittsburgh, Pa.
Philadelphia Quartz Co., Third & Ionic Sts., Philadelphia 6, Pa.
Standard Silicate Div., Diamond Alkali Co., Pittsburgh, Pa.

CONCRETE MIXERS
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.

CONCRETE PIPE
American Concrete Pipe Assn., 33 W. Grand Ave., Chicago 10, Ill.
Lock-Joint Pipe Co., P. O. Box 269, East Orange, N. J.

CONDENSERS (Steam)
Allis-Chalmers Mfg. Co., Milwaukee 1, Wis.
Amer. Cast Iron Pipe Co., Birmingham, Ala.
General American Process Equipment, 420 Lexington Ave., New York 17, N. Y.
Nooter, John, Boiler Works Co., 1410 S. 2nd St., St. Louis 4, Mo.
U. S. Pipe & Foundry Co., Burlington, N. J.
Worthington Pump & Machy. Corp., Harrison, N. J.

CONTRACTORS (Water & Sewage Works)
Master Builders Co., Cleveland, Ohio.
Cement Gun Co., P. O. Box 424, Allentown, Pa.

CONTROLLERS, FLOW, LEVEL, PRESSURE, TEMPERATURE
Automatic Control Co., 1013 University Ave., St. Paul 4, Minn.
Automatic Control Div., Climax Industries, 1949 S. Western Ave., Chicago, Ill.
B/W Controller Corp., Birmingham, Mich.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Clark Controller Co., 1146 E. 152nd St., Cleveland, O.
The Foxboro Co., Foxboro, Mass.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lapp Insulator Co., Le Roy, N. Y.
F. B. Leopold Co., Inc., 422 First Ave., Pittsburgh, Pa.
Leupold & Stevens Instruments, 4445 N. E. Glisan St., Portland 13, Ore.
McAlear Mfg. Co., 1949 S. Western Ave., Chicago 8, Ill.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Roberts Filter Mfg. Co., Darby, Pa.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
Wallace & Tiernan Co., Inc., Newark 1, N. J.

CONVEYORS AND CONVEYING EQUIPMENT
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Dracco Corp., Cleveland, Ohio
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Mfg. Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Omega Machine Co., 3409 E. 18th St., Kansas City, Mo.

COOLING TOWERS
Dresser Industries, Inc., Cleveland 13, Ohio.
Nooter, John, Boiler Works Co., 1410 S. 2nd St., St. Louis 4, Mo.
Stacey Bros. Gas Construction Co., 5535 Vine St., Cincinnati 16, Ohio.

COPPER, BRASS, BRONZE
American Brass Co., Waterbury, Conn.
Glauber Brass Mfg. Co., Kinsman, Ohio.
Hays Mfg. Co., Erie, Pa.
Mueller Brass Co., Port Huron, Mich.
Northrop & Co., Inc., Spring Valley, N. Y.

COPPERAS (Sulphate of Iron)
Innis-Speiden & Co., 117 Liberty St., New York City.
E. M. Sergeant Pulp & Chemical Co., Inc., 7 Dey St., New York 7, N. Y.

COPPER SULPHATE
General Chemical Co., 40 Rector St., New York 6, N. Y.
Innis-Speiden & Co., 117 Liberty St., New York City.
Phelps Dodge Refg. Corp., 40 Wall St., New York, N. Y.
E. M. Sergeant Pulp & Chemical Co., Inc., 7 Dey St., New York 7, N. Y.
Tennessee Corp., 621 Grant Bldg., Atlanta, Ga.

COPPER TUBE
American Brass Co., Waterbury, Conn.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Hays Mfg. Co., Erie, Pa.
Mueller Brass Co., Port Huron, Mich.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., Spring Valley, N. Y.

CORROSION SUPPRESSION
Belco Ind. Equip. Div., 50 Iowa Ave., Patterson 3, N. J.
Calgon, Inc., Hagan Bldg., Pittsburgh, Pa.
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago, Ill.
Electro Rust-Proofing Co., 29 W. Apple St., Dayton, Ohio.
Federal Telephone and Radio Co., Newark 1, N. J.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.

COUPLINGS & CONNECTIONS, PIPE
American Hard Rubber Co., 11 Mercer St., New York 13, N. Y.

Automatic Control Div., Climax Industries, 1949 S. Western Ave., Chicago, Ill.
A. M. Byers Co., Pittsburgh, Pa.
Dresser Mfg. Div., Bradford, Pa.
Glauber Brass Mfg. Co., Kinsman, Ohio.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hays Mfg. Co., Erie, Pa.
McAlear Mfg. Co., 1949 S. Western Ave., Chicago 8, Ill.
Mueller Brass Co., Port Huron, Mich.
Mueller Co., Decatur, Ill.
National Tube Co., Frick Bldg., Pittsburgh, Pa.
Northrop & Co., Inc., Spring Valley, N. Y.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Victaulic Co. of America, 30 Rockefeller Plaza, New York, N. Y.

COUPLINGS, FLEXIBLE
Automatic Control Div., Climax Industries, 1949 S. Western Ave., Chicago, Ill.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
De Laval Steam Turbine Co., Trenton, N. J.
Dresser Mfg. Div., Bradford, Pa.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 220 S. Belmont Ave., Indianapolis 6, Ind.
Peerless Pump Division, Food Machinery Corp., 301 West Avenue 26, Los Angeles 31, Calif.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Victaulic Co. of America, 30 Rockefeller Plaza, New York, N. Y.

COVERS, HANDHOLE, MANHOLE, SAMPLING
Josam Mfg. Co., 1783 East 11th St., Cleveland, Ohio.
Nooter, John, Boiler Works Co., 1410 2nd St., St. Louis 4, Mo.
Northrop & Co., Inc., Spring Valley, N. Y.
Stacey Bros. Gas Construction Co., 5535 Vine St., Cincinnati 16, Ohio.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.

CULVERT CLEANERS
Champion Corp., Hammond, Ind.
W. H. Stewart, P. O. Box 767, Syracuse, N. Y.

CULVERT PIPE
(See Pipe, Culvert)

CURB BOXES
Central Foundry Co., 386 Fourth Ave., New York City.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Hays Mfg. Co., Erie, Pa.
Mueller Co., Decatur, Ill.
Northrup & Co., Inc., 50 Church St., New York 7, N. Y.

CURB STOPS
Glauber Brass Mfg. Co., Kinsman, Ohio.

DECHLORINATING EQUIPMENT AND CHEMICALS
American Water Softener Co., Philadelphia 33, Pa.
Chem-Feeds, Inc., 77 Reservoir Ave., Providence, R. I.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
General Chemical Co., 40 Rector St., New York, N. Y.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lapp Insulator Co., Le Roy, N. Y.
Omega Machine Co., Inc., 9 Codding St., Providence 1, R. I.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Virginia Smelting Co., West Norfolk, Va.
Wallace & Tiernan Co., Inc., Newark 1, N. J.

DE-MINERALIZATION (Water)
Belco Ind. Equip. Div., 50 Iowa Ave., Patterson 3, N. J.
Dorr Co., 570 Lexington Ave., New York 22, N. Y.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Liquid Conditioning Corp., Linden, N. J.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.

DIAPHRAGM, PUMP
(See Pumps, Diaphragm)

DIESEL ENGINES
(See Engines, Diesel)

DIFFUSERS—PLATES & TUBES
Carborundum Co., Perth Amboy, N. J.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.

DIGESTER EQUIPMENT (Sludge)
American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City.
Dorr Co., 570 Lexington Ave., New York City.
Hardinge Co., York, Pa.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Nooter, John, Boiler Works Co., 1410 S. 2nd St., St. Louis 4, Mo.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Walker Process Equip., Inc., Aurora, Ill.
Yeomans Brothers Co., 1433 N. Dayton St., Chicago 22, Ill.

DISTRIBUTORS (Sewage Filter)
American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Yeomans Brothers Co., 1433 N. Dayton St., Chicago 22, Ill.

DRILLING & BORING EQUIPMENT
Hydrauger Corp., Ltd., 116 New Montgomery St., San Francisco, Cal.

DRIVES, CHAIN
(See Chains)

DRIVES, RIGHT ANGLE GEAR
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Payne Dean Co., Madison, Conn.

DRY CHEMICAL FEEDERS
(See Chemical Feeding Equipment)

DRYERS, ROTARY
Allis-Chalmers Mfg. Co., Milwaukee 1, Wis.
General American Process Equipment, 420 Lexington Ave., New York 17, N. Y.
Hersey Mfg. Co., E and First Sts., South Boston 21, Mass.
Link-Belt Co., 300 W. Pershing Rd., Chicago 9, Ill.

EJECTORS, PNEUMATIC OR STEAM (For Sewage and Sludge)
Yeomans Bros. Co., 1423 N. Dayton St., Chicago 22, Ill.

ELECTRICAL CONTROL EQUIPMENT
Clark Controller Co., 1146 E. 152nd St., Cleveland 10, Ohio.
General Electric Corp., Schenectady, N. Y.

ELECTRICALLY OPERATED GATE VALVES
(See Valves, Motor Operated)

ELEVATING AND CONVEYING EQUIPMENT
(See Conveyors & Conveying Equipment)

ENGINE-GENERATOR UNITS
Climax Engineering Co., Clinton, Iowa.
De Laval Steam Turbine Co., Trenton, N. J.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Homelite Corp., Port Chester, N. Y. (Gasoline Engine Driven and Portable.)
Le Roi Co., 1706 S. 68th St., Milwaukee 14, Wis.
Northrop & Co., Inc., Spring Valley, N. Y. (Gasoline Driven Portable.)
Worthington Pump & Machy. Corp., Harrison, N. J.

ENGINES, DIESEL
Climax Engineering Co., Clinton, Iowa.
Cooper-Bessemer Corp., Mount Vernon, Ohio.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Worthington Pump & Machy. Corp., Harrison, N. J.

ENGINES, DUAL FUEL
Cooper Bessemer Corp., Mt. Vernon, O.
Worthington Pump & Mach. Corp., Harrison, N. J.

ENGINES (Gas & Gasoline)
Allis-Chalmers Mfg. Co., Milwaukee 1, Wis.
Buffalo Gasolene Motor Co., Buffalo 13, N. Y.
Climax Engineering Co., Clinton, Iowa.
Cooper-Bessemer Corp., Mount Vernon, Ohio.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Le Roi Co., 1706 S. 68th St., Milwaukee 14, Wis.
Worthington Pump & Machy. Corp., Harrison, N. J.

ENGINES, SLUDGE GAS
Cooper-Bessemer Corp., Mount Vernon, Ohio.
Climax Engineering Co., Clinton, Iowa.
Worthington Pump & Machy. Corp., Harrison, N. J.

EXPANSION JOINTS—PIPE
(See Joints—Expansion, Pipe)

EXHAUSTERS, AIR
(See Pump, Vacuum)

FANS, EXHAUST AND VENTILATING
Jeffrey Mfg. Co., The, 968-99 N. 4th St., Columbus 16, Ohio.
Lakeside Engineering Corp., 222 W. Adams St., Chicago, Ill.

FEED, CHEMICAL
(See Chemical Feeding Equipment.)

FEED WATER FILTERS
Allis-Chalmers Mfg. Co., Milwaukee 1, Wis.
American Water Softener Co., Philadelphia 33, Pa.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
F. B. Leopold Co., Inc., 422 First Ave., Pittsburgh, Pa.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Roberts Filter Mfg. Co., Darby, Pa.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
Worthington Pump & Machinery Corp., Harrison, N. J.

FEED WATER HEATERS
American Water Softener Co., Philadelphia 33, Pa.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Worthington Pump & Machy. Corp., Harrison, N. J.

FERRIC CHLORIDE
Diamond Alkali Co., Pittsburgh, Pa.
General Chemical Co., 40 Rector St., New York City.
Innis, Speiden & Co., 117 Liberty St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia 7, Pa. (Liquid.)

FERRIC CHLORIDE FEEDERS
(See Chemical Feed and Proportioning Equipment)

FERRIC SULFATE
Tennessee Corp., 621 Grant Bldg., Atlanta, Ga.

FERROUS SULFATE
General Chemical Co., 40 Rector St., New York City.
Innis, Speiden & Co., 117 Liberty St., New York City.
E. M. Sergeant Pulp & Chemical Co., Inc., 7 Dey St., New York 7, N. Y.

FIBRE PIPE
(See Pipe, Fibre)

FILTER ALUM
Activated Alum Corp., Curtis Bay, Baltimore, Md.
General Chemical Co., 40 Rector St., New York 6, N. Y.
Penn Salt Mfg. Co., Widener Bldg., Philadelphia 7, Pa.
E. M. Sergeant Pulp & Chemical Co., Inc., 7 Dey St., New York 7, N. Y.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

FILTERING EQUIPMENT
American Water Softener Co., Philadelphia 33, Pa.
American Well Works, Aurora, Ill.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
R. D. Cole Mfg. Co., Newnan, Ga.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Pacific Flush-Tank Co., 4241 Ravenswood Ave., Chicago 3, Ill.
General American Process Equipment, 420 Lexington Ave., New York 17, N. Y.
Hardinge Co., Inc., York, Pa.
Holyoke Mfg. Co., Holyoke, Mass.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
F. B. Leopold Co., Inc., 422 First Ave., Pittsburgh, Pa.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Sanequipment Engr. Co., 2843 Whitewood Drive, Ann Arbor, Mich.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Walker Process Equip. Co., Aurora, Ill.
Worthington Pump & Machinery Corp., Harrison, N. J.

FILTER PLATES AND TUBES
Carborundum Co., Perth Amboy, N. J
Chicago Pump Co., 2336 Wolfram St., Chicago, Ill.

FILTER RATE CONTROLLERS & GAGES
(See Rate Controllers.)

FILTER UNDERDRAINS, SEWAGE
American Well Works, Aurora, Ill.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.
Nat'l Clay Pipe Mfrs., Inc., 111 W. Washington St., Chicago, Ill.

FILTER UNDERDRAINS, WATER
American Water Softener Co., Philadelphia 33, Pa.
Carborundum Co., Niagara Falls, N. Y.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
F. B. Leopold Co., Inc., 422 First Ave., Pittsburgh, Pa.
Nat'l Clay Pipe Mfrs., Inc., 111 W. Washington St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Roberts Filter Mfg. Co., Darby, Pa.

FILTER WASH CONTROL
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Foxboro Co., Foxboro, Mass.
Hardinge Co., Inc., York, Pa.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Permutit Co., 330 W. 42nd St., York 18, N. Y.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

FISH SCREEN
Electric Fish Screen Co., Hollywood 45, Calif.

FITTINGS, PIPE, SOLDER TYPE
American Brass Co., Waterbury, Conn.
American Smelting and Refining Co., 120 Broadway, New York City.
Hays Mfg. Co., Erie, Pa.
Mueller Brass Co., Port Huron, Mich.
Northrop & Co., Inc., Spring Valley, N. Y.

FITTINGS, TEES, ELLS, ETC.
Albert Pipe Supply Co., Inc., Berry and N. 13th St., Brooklyn 11, N. Y.
American Cast Iron Pipe Co., Birmingham, Ala.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Carson-Cadillac Corp., Birmingham, Ala.
Central Foundry Co., 386 Fourth Ave., New York, N. Y.
Crane Co., 836 S. Michigan Av., Chicago, Ill.
Dresser Mfg. Div., Bradford, Pa.
Glauber Brass Mfg. Co., Kinsman, Ohio.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hays Mfg. Co., Erie, Pa.
M & H Valve & Fittings Co., anniston, Ala.
Mueller Brass Co., Port Huron, Mich.
Mueller Co., Decatur, Ill.
Nat'l Clay Pipe Mfrs., Inc., 111 W. Washington St., Chicago, Ill.
Northrop & Co., Inc., Spring Valley, N. Y.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
U. S. Pipe & Foundry Co., Burlington, N. J.
Victaulic Co. of America, 30 Rockefeller Plaza, New York, N. Y.
Warren Foundry & Pipe Corp., 11 Broadway, New York City.
R. D. Wood Co., Public Ledger Bldg., Independence Square, Philadelphia, Pa.

FLASH MIXING EQUIPMENT
(See Mixers & Mixing Equipment)

FLEXIBLE JOINTS
(See Joints, Flexible Pipe.)

FLOATING COVERS (Digester)
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

FLOCCULATING EQUIPMENT
American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Liquid Conditioning Corp., Linden, N. J.
Omega Machine Co., Inc., 9 Codding St., Providence 1, R. I.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Roberts Filter Mfg. Co., Darby, Pa.
Stuart Corp., 516 N. Charles St., Baltimore, Md.
Vogt Mfg. Co., Louisville, Ky.
Walker Process Equip., Inc., Aurora, Ill.
Wallace & Tiernan Co., Inc., Newark 1, N. J.
Yeomans Bros. Co., 1423 N. Dayton St., Chicago 22, Ill.

FLOOR STANDS
American Car & Fdy. Co., 30 Church St., New York 8, N. Y.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Eddy Valve Co., Waterford, N. Y.
Rodney Hunt Machine Co., Orange, Mass.
Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa.
F. B. Leopold Co., 422 First Ave., Pittsburgh, Pa.
Ludlow Valve Mfg. Co., Troy, N. Y.
M & H Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Merco Nordstrom Valve Co., Lexington Ave., Pittsburgh, Pa.
Rensselaer Valve Co., Troy, N. Y.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., Public Ledger Bldg., Independence Square, Philadelphia, Pa.

FLOW METERS
American Meter Co., 60 E. 42nd St., New York City.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Foxboro Co., Foxboro, Mass.
Northrop & Co., Inc., Spring Valley, N. Y.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Roots-Connersville Blower Corp., Connersville, Ind.
Simplex Valve & Meter Co., Philadelphia, Pa.
R. W. Sparling, Box 3277 Terminal Annex, Los Angeles, Calif.

FLOW RECORDERS
(See Rate of Flow Recorders)

FLOW REGULATORS
(See Rate of Flow Controllers)

FLUMES, IRON & STEEL
Armco Drainage Products Assn., Middletown, Ohio.
Chicago Bridge & Iron Company, 2198 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Rodney Hunt Machine Co., Orange, Mass.
Nooter, John, Boiler Works Co., 1410 S. 2nd St., St. Louis 4, Mo.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

FOOT VALVE WITH STRAINER
(See Valves, Foot)

FORMS & GASKETS FOR PIPE JOINTS
Johns-Manville, 22 E. 40th St., New York City.
L. A. Weston, Adams, Mass.

FURNACES, MELTING, POURING LADLES, POTS, ETC.
Atlas Mineral Products Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., Spring Valley, N. Y.

GAGES (Liquid Level, Pressure Recording)
American Meter Co., 60 E. 42nd St., New York City.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Foxboro Co., Foxboro, Mass.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Leupold & Stevens Instruments, 4445 N. E. Glisan St., Portland 13, Ore.
Northrop & Co., Inc., Spring Valley, N. Y.
Pacific Flush-Tank Co., 4241 Ravenswood Ave., Chicago 3, Ill.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.
Wallace & Tiernan Co., Inc., Newark, N. J.

GARBAGE GRINDERS
(See Grinders)

GAS DIFFUSERS
American Well Works, Aurora, Ill.
Carborundum Co., Perth Amboy, N. J.
Chicago Pump Co., 2336 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Vogt Mfg. Co., Louisville, Ky.
Walker Process Equip., Inc., Aurora, Ill.

GAS ENGINES
(See Engines, Gas & Gasoline)

GAS HOLDERS
Chicago Bridge & Iron Company, 2198 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Dresser Industries, Inc., Cleveland 13, Ohio.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Stacey Bros. Gas Construction Co., 5535 Vine St., Cincinnati 16, Ohio.

GAS HOLDER INSPECTION SERVICE
Dresser Industries, Inc., Cleveland 13, Ohio
Stacey Bros. Gas Construction Co., 5535 Vine St., Cincinnati 16, Ohio.

GAS INDICATORS AND DETECTORS
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

GAS PURIFICATION
Connelly, Inc., 3154 S. California Ave., Chicago, Ill.
Stacey Bros. Gas Construction Co., 5535 Vine St., Cincinnati 16, Ohio.

GATES, ROLLER
Hunt, Rodney, Machine Co., Orange, Mass.

GATES, SHEAR
Chapman Valve Mfg. Co., 203 Hampshire St., Indian Orchard, Mass.
Eddy Valve Co., Waterford, N. Y.
Rodney Hunt Machine Co., Orange, Mass.
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa.
Ludlow Valve Mfg. Co., Troy, N. Y.
M & H Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Rensselaer Valve Co., Troy, N. Y.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., Public Ledger Bldg., Independence Square, Philadelphia, Pa.

GATES, SLUICE
Filer and Stowell Co., Milwaukee 7, Wis.
Armco Drainage Products Assn., Middletown, Ohio.
Chapman Valve Mfg. Co., 203 Hampshire St., Indian Orchard, Mass.
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa.
Ludlow Valve Mfg. Co., Troy, N. Y.
Mueller Co., Chattanooga, Tenn.
Rensselaer Valve Co., Troy, N. Y.
S. Morgan Smith Co., York, Pa.

GATE VALVE OPERATOR
Payne Dean & Co., Madison, Conn.
Rensselaer Valve Co., Troy, N. Y.

GATE VALVES
(See Valves, Gate)

GEARS, SPEED REDUCING
De Laval Steam Turbine Co., Trenton, N. J.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Worthington Pump & Machy. Corp., Harrison, N. J.

GENERATOR SETS, GAS & DIESEL ENGINES
(See Engine Generating Units)

GOOSENECKS
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hays Mfg. Co., Erie, Pa.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., Spring Valley, N. Y.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.

GREEN SAND (Zeolite)
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago, Ill.
Liquid Conditioning Corp., Linden, N. J.
Permutit Co., 330 W. 42nd St., York 18, N. Y.
Roberts Filter Mfg. Co., Darby, Pa.
Zeolite Chemical Co., 140 Cedar New York 6, N. Y.

GRINDERS, GARBAGE & SCREENINGS
Allis-Chalmers Mfg. Co., Milwaukee 1, Wis.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
General Electric Co. (household), Bridgeport, Conn.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 Hunting Park Ave., Philadelphia, Pa.

GRATINGS
Blaw-Knox Div., Farmers Bank Bldg., Pittsburgh 22, Pa.

GRIT CHAMBER EQUIPMENT
American Well Works, Aurora, Ill.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engineering Corp., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Walker Process Equip., Inc., Aurora, Ill.

GROUND KEY STOPS
Glauber Brass Mfg. Co., Kinsman, Ohio.

GUNITING CONTRACTING
Cement Gun Co., P. O. Box 424, Allentown, Pa.

HOSE, STEAM, AIR, WATER, SUCTION
American Brass Co., Waterbury, Conn.
Edson Corp., 49 D St., So. Boston, Mass.
Gardner-Denver Co., Quincy, Ill.
Jaeger Machine Co., 716 Dublin Ave., Columbus, Ohio.
Northrop & Co., Inc., Spring Valley, N. Y.

HYDRANT PUMPS
(See Pumps, Hydrant)

HYDRANTS (Fire)
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Eddy Valve Co., Waterford, N. Y.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y
M & H Valve & Fittings Co., Anniston, Ala.
Mueller Co., Decatur, Ill.
Rensselaer Valve Co., Troy, N. Y.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., Public Ledger Bldg., Independence Square, Philadelphia, Pa.

HYDRAULICALLY OPERATED GATE VALVES
(See Valves, Gate)

HYDROGEN ION EQUIPMENT
(See pH Test Equipment.)

HYDROGEN SULFIDE REMOVAL (Gas)
Connelly, Inc., 3154 S. California Ave., Chicago, Ill.

HYPO-CHLORINATORS
American Water Softener Co., Philadelphia 33, Pa.
Chem-Feeds-Inc., 77 Reservoir Ave., Providence, R. I.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago, Ill.
Lapp Insulator Co., Le Roy, N. Y.
Milton Roy Co., Chestnut Hill, Philadelphia 18, Pa.
Omega Mach. Co., Inc., 9 Codding St., Providence 1, R. I.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Newark 1, N. J.

HYPOCHLORITES (High Test)
(See Calcium Hypochlorite)

INCINERATORS
Dorr Co., Inc., 570 Lexington Ave., New York City.
Morse Boulger Destructor Co., 205 E. 42nd St., New York City.
Nichols Engr. & Research Corp., 60 Wall Tower, New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

INDICATORS, LARGE DIAL, ILLUMINATED
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, O.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Foxboro Co., Foxboro, Mass.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Leupold & Stevens Instruments, 4445 N. E. Glisan St., Portland 13, Ore.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
R. W. Sparling, Box 3277 Terminal Annex, Los Angeles, Calif.

INSTRUMENTS (Meteorological)
M. C. Stewart, Ashburnham, Mass.

INSTRUMENTS (Surveying, Hydrographic and Navigation)
Leupold & Stevens Instruments, 4445 N. E. Glisan St., Portland 13, Oregon.

INSULATION
Carborundum Co., Perth Amboy, N. J.
Ford Meter Box Co., Wabash, Ind. (Water Meter).
Johns-Manville, 22 E. 40th St., New York City.

IRON SULFATE
(See Ferric Sulfate, or Ferrous Sulfate)

JOINTING COMPOUND AND MATERIALS
Atlas Mineral Prod. Co., Mertztown, Pa.
J. H. Grancell, 1601 E. Nadeau St., Los Angeles 1, Calif.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hydraulic Development Corp., 50 Church St., New York City.
Inertol Co., Newark, N. J.
Leadite Co., Philadelphia, Pa.
Michael Hayman & Co., 870 E. Ferry St., Buffalo, N. Y.
Northrop & Co., Inc., Spring Valley, N. Y.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.
Rensselaer Valve Co., Troy, N. Y.
Servicised Products Corp., 6051 West 65th St., Chicago, Ill.
Wailes Dove-Hermiston, Westfield, N. J.

JOINTS, EXPANSION—PIPE
Amer. Cast Iron Pipe Co., Birmingham, Ala.
Automatic Control Div., Climax Industries, 1949 S. Western Ave., Chicago, Ill.
Central Foundry Co., 386 Fourth Ave., N. Y., N. Y.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Div., Bradford, Pa.
Josam Mfg. Co., 1783 East 11th St., Cleveland, Ohio.
Lock Joint Pipe Co., P. O. Box 269, East Orange, N. J.
Nat'l Clay Pipe Mfrs., Inc., 111 W. Washington St., Chicago, Ill.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.

JOINTS, MECHANICAL, FLEXIBLE
American Cast Iron Pipe Co., Birmingham, Ala.
Automatic Control Div., Climax Industries, 1949 S. Western Ave., Chicago, Ill.
Carson-Cadillac Corp., Birmingham, Ala.
Central Foundry Co., 386 Fourth Ave., New York City.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dresser Mfg. Div., Bradford, Pa.
Hays Mfg. Co., Erie, Pa.
Lock Joint Pipe Co., P. O. Box 269, East Orange, N. J.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
U. S. Pipe & Foundry Co., Burlington, N. J.
Victaulic Co. of America, 30 Rockefeller Plaza, New York, N. Y.
Warren Foundry & Pipe Corp., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

JUTE, BRAIDED AND TWISTED
Atlas Mineral Prod. Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Johns-Manville, 22 E. 40th St., New York City.
Northrop & Co., Inc., Spring Valley, N. Y.

LABORATORY APPARATUS AND REAGENTS
Chemlab Specialties Co., 52 Alvarado Road, Berkeley, Calif.
Fleischer Chem. Co., P. O. Box 616, Washington 4, D. C.
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
Klett Mfg. Co., 179 E. 87th St., New York 28, N. Y.
LaMotte Chem. Co., Tucson 4, Md.
Nat'l Technical Labs, Los Angeles, Calif.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., Sixth & Byrd, Richmond, Va.

W. A. Taylor & Co., 7300 York Rd., Baltimore, Md.
Wallace & Tiernan Co., Inc., Newark 1, N. J.

LEAK LOCATING INSTRUMENTS
(See Water Leak Locating Instruments)

LIQUID CHLORINE
(See Chlorine, Liquid.)

LOCATORS, BOX, PIPE AND VALVE
(See Respective Headings.)

MANOMETERS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Foxboro Co., Foxboro, Mass.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago, Ill.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.

METER ACCESSORIES, BOXES, HOUSING SETTING, ETC.
Badger Meter Co., Milwaukee, Wis.
Buffalo Meter Co., 2909 Main St., Buffalo, N. Y.
Foxboro Co., Foxboro, Mass.
Ford Meter Box Co., Wabash, Ind.
Glauber Brass Mfg. Co., Kinsman, Ohio.
Meter Specialty Co., 1332 N. 7th St., Memphis, Tenn.
Mueller Co., Decatur, Ill.
Nat'l Clay Pipe Mfrs., Inc., 111 W. Washington St., Chicago, Illinois.
Northrop & Co., Inc., Spring Valley, N. Y.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

METER COUPLINGS & YOKES
American Meter Co., 60 E. 42nd St., New York City.
Badger Meter Mfg. Co., Milwaukee, Wis.
Buffalo Meter Co., 2909 Main St., Buffalo, N. Y.
Ford Meter Box Co., Wabash, Ind.
Glauber Brass Mfg. Co., Kinsman, Ohio.
Hays Mfg. Co., Erie, Pa.
Hersey Mfg. Co., E and First Sts., South Boston 21, Mass.
Mueller Co., Decatur, Ill.
Neptune Meter Co., 50 West 50th St., New York City.
Northrop & Co., Inc., Spring Valley, N. Y.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

METERS, GAS
American Meter Co., 60 E. 42nd St., New York City.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, O.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Foxboro Co., Foxboro, Mass.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Roots-Connersville Blower Corp., Connersville, Ind.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

METER TESTING EQUIPMENT
American Meter Co., 60 E. 42nd St., New York City.
Badger Meter Mfg. Co., Milwaukee, Wis.
Buffalo Meter Co., 2909 Main St., Buffalo, N. Y.
Ford Meter Box Co., Wabash, Ind.
Hersey Mfg. Co. E and First Sts., South Boston 21, Mass.
National Meter Division of Pittsburgh Equitable Meter Co., 4259 First Ave., Brooklyn, N. Y.
Neptune Meter Co., 50 W. 50th St., New York City.
Northrop & Co., Inc., Spring Valley, N. Y.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Worthington - Gamon Meter Co., Newark, N. J.

METERS, VENTURI
Bailey Meter Co., 1072 Invanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Foxboro Co., Foxboro, Mass.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Simplex Valve & Meter Co., 68th & Upham Sts., Philadelphia, Pa.

METERS, WATER & SEWAGE
American Meter Co., 60 E. 42nd St. New York City.
Badger Meter Mfg. Co., Milwaukee, Wis.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Buffalo Meter Co., 2909 Main St., Buffalo, N. Y.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Foxboro Co., Foxboro, Mass.
Hersey Mfg. Co., E and First Sts., South Boston 21, Mass.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Neptune Meter Co., 50 W. 50th St., New York City.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
R. W. Sparling, Box 3277 Terminal Annex, Los Angeles, Calif.
Worthington - Gamon Meter Co., Newark, N. J.

METERS (Water), CLEANING SOLUTION
Skasol Corp., Webster Groves, Mo.

MIXERS AND MIXING EQUIPMENT
(Chemical, Water, and Sewage)
American Well Works, Aurora, Ill.
Carborundum Co., Perth Amboy, N. J.
Ralph B. Carter Co., 53 Park Place, New York City.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
General American Process Equipment, 420 Lexington Ave., New York 17, N. Y.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Lapp Insulator Co., Le Roy, N. Y.
F. B. Leopold Co., 422 First Ave., Pittsburgh, Pa.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Liquid Conditioning Corp., Linden, N. J.
Omega Mach. Co., Inc., 9 Codding St., Providence 1, R. I.
Permutit Co., 330 W. 42nd St. New York 18, N. Y.
Roberts Filter Mfg. Co., Darby, Pa.
Vogt Mfg. Co., Louisville, Ky.
Walker Process Equip. Co., Aurora, Ill.
Wallace & Tiernan Co., Inc., Newark, N. J.

MOTORS, ELECTRIC
Allis-Chalmers Mfg. Co., Milwaukee 1, Wis.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
General Electric Co., Schenectady, N. Y.
Westinghouse Electric & Mfg. Co., P. O. Box 868, Pittsburgh 30, Pa.

NIPPLES, PIPE
American Hard Rubber Co., 11 Mercer St., New York 13, N. Y.
A. M. Byers Co., Pittsburgh, Pa.
Dresser Mfg. Co. Div., Bradford, Pa.
Glauber Brass Mfg. Co., Kinsman, Ohio.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hays Mfg. Co., Erie, Pa.
Mueller Brass Co., Port Huron, Mich.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., Spring Valley, N. Y.

NO-OX-ID
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago, Ill.

NOZZLES, FLOW
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Foxboro Co., Foxboro, Mass.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

NOZZLES, SPRAY
Chain Belt Co., Milwaukee, Wis.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Mueller Brass Co., Port Huron, Mich.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Yeomans Bros. Co., 1433 N. Dayton St., Chicago 22, Ill.

OPERATING TABLES (Filter)
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
F. B. Leopold Co., 422 First Ave., Pittsburgh, Pa.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

ORIFICES
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Foxboro Co., Foxboro, Mass.
Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

PACKING
Johns-Manville, 22 E. 40th St., New York City.
Northrop & Co., Inc., Spring Valley, N. Y.

PAINT, ACID RESISTING
Atlas Mineral Prod. Co,, Mertztown, Pa.
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio
Inertol Co., Newark 5, N. J.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.
Wailes Dove-Hermiston, Westfield, N. J.

PENSTOCKS
Chicago Bridge & Iron Co., 2198 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Dresser Industries, Inc., Cleveland 13, Ohio.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Stacey Bros. Gas Construction Co., 5535 Vine St., Cincinnati 16, Ohio.

pH TEST EQUIPMENT
American Water Softening Co., Philadelphia 33, Pa.
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
Beckman Instruments Div., National Technical Laboratories, So. Pasadena, Calif.
LaMotte Chem. Co., Towson 4, Balto, Md.
Phipps & Bird, Inc., 303 S. 6th St., Richmond 5, Va.
W. A. Taylor & Co., 7300 York Rd., Baltimore, Md.
Wallace & Tiernan Co., Inc., Newark, N. J.

PIPE AND TANK COATINGS
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago, Ill.
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Stacey Bros. Gas Construction Co., 5535 Vine St., Cincinnati 16, Ohio.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

PIPE, ASBESTOS-CEMENT
Johns-Manville Co., 22 E. 40th St., New York City.

PIPE BENDING MACHINES
Hays Mfg. Co., Erie, Pa.

PIPE, CAST IRON
Albert Pipe Supply Co., Berry and N. 13th St., Brooklyn 11, N. Y.
American Cast Iron Pipe Co., Birmingham, Ala.
Central Foundry Co., 386 4th Ave., New York City.
Hunt, Rodney, Machine Co., Orange, Mass.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Corp., 11 Broadway, New York City.
R. D. Wood Co., Public Ledger Bldg., Independence Square, Philadelphia, Pa.

PIPE, CEMENT LINED
American Cast Iron Pipe Co., Birmingham, Ala.
Central Foundry Co., 386 Fourth Ave., New York City.
Centriline Corp., 140 Cedar St., New York City.
Preload Enterprises, Inc., 420 Lexington Ave., New York, N. Y.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Corp., 11 Broadway, New York City.

PIPE, CEMENT LINING OF
Centriline Corp., 140 Cedar St., New York City.
Lock Joint Pipe Co., P. O. Box 269, East Orange, N. J.
Preload Enterprises, Inc., 420 Lexington Ave., New York, N. Y.
Tate Pipe Linings, Inc., 47 Haverhill St., Andover, Mass.

PIPE, CONCRETE, PRESSURE
Lock Joint Pipe Co., P. O. Box 269, East Orange, N. J.

PIPE, COPPER, BRASS AND BRONZE
American Brass Co., Waterbury, Conn.
Hays Mfg. Co., Erie, Pa.
Mueller Brass Co., Port Huron, Mich.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., Spring Valley, N. Y.

PIPE, CORRUGATED
Armco Drainage Products Assn., Middletown, Ohio.

PIPE, CULVERT
Armco Drainage Products Assn., Middletown, Ohio.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago.
Central Foundry Co., 386 Fourth Ave., New York City.
Johns-Manville, 22 E. 40th St., New York City.
Lock Joint Pipe Co., P. O. Box 269, East Orange, N. J.
Nat'l Clay Pipe Mfrs., Inc., 111 W. Washington St., Chicago, Ill.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Corp., 11 Broadway, New York City.
R. D. Wood Co., Public Ledger Bldg., Independence Square, Philadelphia, Pa.

PIPE CUTTING MACHINES
Northrop & Co., Inc., Spring Valley, N. Y.
Ridge Tool Co., Elyria, Ohio.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.

PIPE, DRILLS, JACKS AND PUSHERS
Northrop & Co., Inc., Spring Valley, N. Y.

PIPE ENAMELS, PROTECTIVE —COAL TAR

General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Inertol Co., Newark 5, N. J.
Wailes Dove-Hermiston, Westfield, N. J.

PIPE, FELT WRAPPING

Dearborn Chemical Co., 310 S. Michigan Ave., Chicago, Ill.
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Johns-Manville, 22 E. 40th St., New York City.

PIPE, FIBRE

Fibre Conduit Co., Orangeburg, N. Y.

PIPE FITTINGS (See Fittings Pipe)

PIPE—GALVANIZED, LIGHT-WEIGHT (Quick Coupling, Transportable for Conveying Water)

Armco Drainage Products Assoc., Middletown, Ohio.
Champion Corp., Hammond, Ind.

PIPE, HARD RUBBER LINED

American Hard Rubber Co., 11 Mercer St., New York 13, N. Y.

PIPE JOINT COMPOUNDS

(See Jointing Compounds.)

PIPE JOINTS (Mechanical)

Automatic Control Div., Climax Industries, 1949 S. Western Ave., Chicago, Ill.
Carson-Cadillac Corp., Birmingham, Ala.
Central Foundry Co., 386 Fourth Ave., New York, N. Y.
Dresser Mfg. Div., Bradford, Pa.
Hays Mfg. Co., Erie, Pa.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
L. A. Weston, Adams, Mass.
R. D. Wood & Co., Public Ledger Bldg., Independence Square, Philadelphia, Pa.
U. S. Pipe & Foundry Co., Burlington, N. J.

PIPE JOINT TOOLS

Atlas Mineral Products Co., Mertztown, Pa.
Hays Mfg. Co., Erie, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., Spring Valley, N. Y.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

PIPE, LEAD LINED

Nooter, John, Boiler Works Co., 1410 S. 2nd St., St. Louis 4, Mo.

PIPE LOCATORS

Fisher Research Lab., 1961 University Ave., Palo Alto, Calif.
Northrop & Co., Inc., Spring Valley, N. Y.

PIPE PUSHERS

Northrop & Co., Inc., Spring Valley, N. Y.
Hydrauger Corp., Ltd., 116 New Montgomery St., San Francisco, Calif.

PIPE, SEWER

American Cast Iron Pipe Co., Birmingham, Ala.
Am. Concrete Pipe Assn., 33 W. Grand Ave., Chicago, Ill. (Reinforced Concrete.)
Armco Drainage Products Assn., Middletown, Ohio.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Central Foundry Co., 386 Fourth Ave., New York City.
Fibre Conduit Co., Orangeburg, N. Y.
Johns-Manville, 22 E. 40th St., New York City.
Lock Joint Pipe Co., P. O. Box 269, East Orange, N. J.
Nat'l Clay Pipe Mfrs., 111 W. Washington St., Chicago, Ill.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Corp., 11 Broadway, New York City.

PIPE, STEEL (All Types)

Armco Drainage & Metal Products, Inc., Middletown, O.
American Locomotive Co., Alco Products Div., 30 Church St., New York 8, N. Y.
American Rolling Mill Co., Middletown, Ohio.
Chicago Bridge & Iron Company, 2198 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Dresser Industries, Inc., Cleveland 13, Ohio.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Nooter, John, Boiler Works Co., 1410 S. 2nd St., St. Louis 4, Mo.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Stacey Bros. Gas Construction Co., 5535 Vine St., Cincinnati 16, Ohio.

PIPE TAPPING MACHINES

Hays Mfg. Co., Erie, Pa.
Mueller Co., Decatur, Ill.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.

PIPE TEST PLUGS

Northrop & Co., Inc., Spring Valley, N. Y.
Richmond Fdry. & Mfg. Co., Richmond, Va.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.

PIPE TOOLS (Cutters, Extractors, Threaders, Wrenches, Etc.)

Ridge Tool Co., Elyria, Ohio.

PIPE, VITRIFIED CLAY

(See Vitrified Clay Pipe and Products.)

PIPE, WRAPPING

Dearborn Chemical Co., 310 S. Michigan Ave., Chicago, Ill.
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Johns-Manville, 22 E. 40th St., New York City.

PIPE, WROUGHT IRON

A. M. Byers Co., Clark Bldg., Pittsburgh, Pa.

PITOT TUBES

Pitometer Company, 50 Church St., New York City.
Foxboro Co., Foxboro, Mass.
Leupold & Stevens Instruments, 4445 N. E. Glisan St., Portland, Ore.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

PNEUMATIC CONVEYORS FOR WATER AND SEWAGE TREATMENT

Dracco Corp., Cleveland, Ohio.

POROUS TUBES AND PLATES

Carborundum Co., Niagara Falls, N. Y.
Chicago Pump Co., 2336 Wolfram St., Chicago, Ill.

PRESSURE REGULATORS

(See Regulators, Pressure)

PROPORTIONING EQUIPMENT

(See Chemical Feed and Proportioning Equip.)

PUMPING CONTROLS

Automatic Control Co., 1031 University Ave., St. Paul 4, Minn.
B/W Controller Corp., Birmingham, Mich.

PUMP PRIMERS

Barrett, Haentjens & Co., Hazleton, Pa.
Ralph B. Carter Co., 53 Park Place, New York City.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
Roots-Connersville Blower Corp., Connersville, Ind.
Yeoman Bros. Co., 1433 N. Dayton St., Chicago 22, Ill.

PUMPS, ACID-HANDLING

Allis-Chalmers Mfg. Co., Milwaukee 1, Wis.
American Hard Rubber Co., 11 Mercer St., New York 13, N. Y.
Aurora Pump Co., Aurora, Ill.
Ralph B. Carter Co., 53 Park Place, New York City.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dayton-Dowd Pumps, Peerless Pump Division, Inc., Quincy, Illinois.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Lapp Insulator Co., Le Roy, N. Y.
Milton Roy Co., Chestnut Hill, Philadelphia, Pa.
Morris Machine Works, Baldwinsville, N. Y.
Pomona Pump Co., 206 E. Commercial St., Pomona, Calif.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
Wallace & Tiernan Co., Inc., Newark, N. J.
Worthington Pump & Mach. Corp., Harrison, N. J.
Yeoman Bros. Co., 1433 N. Dayton St., Chicago 22, Ill.

PUMPS, CELLAR DRAINER

(See Pumps, Sump)

PUMPS, CENTRIFUGAL

Allis-Chalmers Mfg. Co., Milwaukee 1, Wis.
American Well Works, Aurora, Ill.
Aurora Pump Co., Aurora, Ill.
Barrett, Haentjens & Co., Hazleton, Pa.
Ralph B. Carter Co., 53 Park Place, New York City.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
A. D. Cook Co., Inc., Lawrenceburg, Indiana.
Dayton - Dowd Pumps, Peerless Pump Division, Inc., Quincy, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
Deming Co., Salem, Ohio.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Gardner-Denver Co., Quincy, Ill.
Gorman-Rupp Co., Mansfield, Ohio.
Homelite Corp., Port Chester, N. Y.
Layne & Bowler, Inc., P. O. Box 215, Hollywood Sta., Memphis 8, Tenn.
Morris Machine Works, Baldwinsville, N. Y.
Northrop & Co., Inc., Spring Valley, N. Y.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Worthington Pump & Mach. Corp., Harrison, N. J.
Yeomans Brothers Co., 1433 Dayton St., Chicago 22, Ill.

PUMPS, DEEP WELL

American Well Works, Aurora, Ill.
Aurora Pump Co., Aurora, Ill.
A. D. Cook Co., Inc., Lawrenceburg, Indiana.
Deming Co., Salem, Ohio.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Layne & Bowler, Inc., P. O. Box 215, Hollywood Sta., Memphis 8, Tenn.
Morris Machine Works, Baldwinsville, N. Y.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Pomona Pump Co., 206 E. Commercial St., Pomona, Calif.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS, DIAPHRAGM

Ralph B. Carter Co., 53 Park Place, New York City.
Chem-Feeds-Inc., 77 Reservoir Ave., Providence, R. I.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Deming Co., Salem, Ohio.
Dorr Co., 570 Lexington Ave., New York City.
Edson Corp., 49 D. St., South Boston, Mass.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Lapp Insulator Co., Le Roy, N. Y.
Milton Roy Co., Chestnut Hill, Philadelphia 18, Pa.
Northrop & Co., Inc., Spring Valley, N. Y.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Inc., Newark, N. J.
Yeomans Brothers Co., 1433 Dayton St., Chicago 22, Ill.

PUMPS, DRAINAGE (See Pumps, Sewage and Drainage)

PUMPS, HYDRANT

Edson Corp., 49 D St., South Boston, Mass.
Northrop & Co., Inc., Spring Valley, N. Y.
Yeomans Brothers Co., 1433 Dayton St., Chicago 22, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City.

PUMPS, HYDRAULIC

Ross Valve Mfg. Co. Inc., Troy, N. Y.

PUMPS, JETTING

Ralph B. Carter Co., 53 Park Pl., New York N. Y.
Gorman-Rupp Co., Mansfield, Ohio.
Northrop & Co., Inc., Spring Valley, N. Y.
Peerless Pump Div., Food Machinery Corp., 301 W. Ave. 26, Los Angeles 31, Calif.

PUMPS, PORTABLE

Barrett, Haentjens & Co., Hazleton, Pa.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Chem-Feeds-Inc., 77 Reservoir Ave., Providence, R. I.
Dayton - Dowd Pumps, Peerless Pump Div., Inc., Quincy, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
Deming Co., Salem, Ohio.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Gorman-Rupp Co., Manafield, Ohio.
Homelite Corp., Port Chester, N. Y.
Morris Machine Works, Baldwinsville, N. Y.
Northrop & Co., Inc., Spring Valley, N. Y.
Peerless Pump Division Food Machinery Corp., 301 West Avenue 26, Los Angeles, Calif.
Pomona Pump Co., 206 E. Commercial St., Pomona, Calif.
Worthington Pump & Mach. Corp., Harrison, N. J.
Yeomans Brothers Co., 1433 N. Dayton St., Chicago 22, Ill.

PUMPS, ROTARY

De Laval Steam Turbine Co., Trenton, N. J.
Deming Co., Salem, Ohio.
Dresser Industries, Inc., Cleveland 13, Ohio.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Layne & Bowler, Inc., P. O. Box 215, Hollywood Station, Memphis 8, Tenn.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Pomona Pump Co., 206 E. Commercial St., Pomona, Calif.
Roots-Connersville Blower Corp., Connersville, Ind.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS, SELF PRIMING

Allis-Chalmers Mfg. Co., Milwaukee 1, Wis.
Aurora Pump Co., Aurora, Ill.
Barrett, Haentjens & Co., Hazleton, Pa.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dayton - Dowd Pumps, Peerless Pump Div., Quincy, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
Deming Co., Salem, Ohio.
Gorman-Rupp Co., Mansfield, Ohio.
Homelite Corp., Port Chester, N. Y.

Layne & Bowler, Inc., P. O. Box 215, Hollywood Sta., Memphis 8, Tenn.
Peerless Pump Div., Food Machinery Corp., 301 W. Ave. 26, Los Angeles 31, Calif.
Pomona Pump Co., 206 E. Commercial St., Pomona, Calif.
Roots-Connersville Blower Corp., Connersville, Ind.
Worthington Pump & Mach. Corp., Harrison, N. J.
Yeomans Brothers Co., 1433 N. Dayton St., Chicago 22, Ill.

PUMPS, SEWAGE AND DRAINAGE

Allis-Chalmers Mfg. Co., Milwaukee 1, Wis.
American Well Works, Aurora, Ill.
Aurora Pump Co., Aurora, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dayton - Dowd Pumps, Peerless Pump Div., Inc., Quincy, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
Deming Co., Salem, Ohio.
Edson Corp., 49 D St., South Boston, Mass.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Gorman-Rupp Co., Mansfield, Ohio.
Morris Machine Works, Baldwinsville, N. Y.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Pomona Pump Co., Pomona, Calif.
S. Morgan Smith Co., York, Pa.
Worthington Pump & Mach. Corp., Harrison, N. J.
Yeomans Brothers Co., 1433 N. Dayton St., Chicago 22, Ill.

PUMPS, SLUDGE

Allis-Chalmers Mfg. Co., Milwaukee 1, Wis.
American Well Works, Aurora, Ill.
Aurora Pump Co., Aurora, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dayton - Dowd Pumps, Peerless Pump Div., Inc., Quincy, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
Deming Co., Salem, Ohio.
Dorr Co., 570 Lexington Ave., New York City.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Morris Machine Works, Baldwinsville, N. Y.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Peerless Pump Division Food Machinery Corp., 301 West Avenue 26, Los Angeles, Calif.
Pomona Pump Co., 206 E. Commercial St., Pomona, Calif.
Worthington Pump & Mach. Corp., Harrison, N. J.
Yeomans Brothers Co., 1433 N. Dayton St., Chicago 22, Ill.

PUMPS, SUMP (AND CELLAR DRAINER)

American Well Works, Aurora, Ill.
Aurora Pump Co., Aurora, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dayton - Dowd Pumps, Peerless Pump Div., Inc., Quincy, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
Deming Co., Salem, Ohio.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Gorman-Rupp Co., Mansfield, Ohio.
Morris Machine Works, Baldwinsville, N. Y.
Peerless Pump Division Food Machinery Corp., 301 West Avenue 26, Los Angeles, Calif.
Pomona Pump Co., 206 E. Commercial St., Pomona, Calif.
Worthington Pump & Mach. Corp., Harrison, N. J.
Yeomans Brothers Co., 1433 N. Dayton St., Chicago 22, Ill.

PUMPS, TURBINE

American Well Works, Aurora, Ill.
Aurora Pump Co., Aurora, Ill.
Dayton - Dowd Pumps, Peerless Pump Div., Inc., Quincy, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
Deming Co., Salem, Ohio.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Layne & Bowler, Inc., P. O. Box 215, Hollywood Sta., Memphis 8, Tenn.
Morris Machine Works, Baldwinsville, N. Y.
Peerless Pump Division Food Machinery Corp., 301 West Avenue 26, Los Angeles 31, Calif.
Pomona Pump Co., 206 E. Commercial St., Pomona, Calif.
S. Morgan Smith Co., York, Pa.
Worthington Pump & Mach. Corp., Harrison, N. J.
Yeomans Brothers Co., 1433 N. Dayton St., Chicago 22, Ill.

PUMPS, VACUUM

Allis-Chalmers Mfg. Co., Milwaukee 1, Wis.
Barrett, Haentjens & Co., Hazleton, Pa.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Roots-Connersville Blower Corp., Connersville, Ind.
Vogt Brothers Mfg. Co., Louisville, Ky.
Worthington Pump & Mach. Corp., Harrison, N. J.
Yeomans Brothers Co., 1433 N. Dayton St., Chicago 22, Ill.

RAIN GAGES

M. C. Stewart, Ashburnham, Mass.

RATE OF FLOW CONTROLLERS

American Meter Co., 60 E. 42nd St., New York City.
Automatic Control Div., Climax Industries, 1949 S. Western Ave., Chicago, Ill.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Fischer & Porter Co., Hatboro, Pa.
Foxboro Co., Foxboro, Mass.
Infilco, Inc., 325 W. 25th Place., Chicago, Ill.
McAlear Mfg. Co., 1949 S. Western Ave., Chicago 8, Ill.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
S. Morgan Smith Co., York, Pa.

RATE OF FLOW RECORDERS

American Meter Co., 60 E. 42nd St., New York City.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
F. S. Brainard & Co., 246 Palm St., Hartford, Conn.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Foxboro Co., Foxboro, Mass.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
Leupold & Stevens Instruments, 4445 N. E. Glisan St., Portland 13, Ore.
Northrop & Co., Inc., Spring Valley, N. Y.
Permutit Co., 330 W. 42nd St., New York City.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
R. W. Sparling, Box 3277 Terminal Annex, Los Angeles, Calif.

REAMERS

Mueller Co., Decatur, Ill.
Ridge Tool Co., Elyria, Ohio.

RECARBONATORS

(See Carbonators)

REFRACTORIES

Carborundum Co., Perth Amboy, N. J.
Johns-Manville, 22 E. 40th St., New York City.

REGULATORS, PRESSURE

(Water and Gas)
American Meter Co., 60 E. 42nd St., New York City.
American Radiator Co., Bessemer Bldg., Pittsburgh, Pa.
Automatic Control Div., Climax Industries, 1949 S. Western Ave., Chicago, Ill.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Clark Controller Co., 1146 E. 152nd St., Cleveland 10, Ohio.
Clayton Mfg. Co., Alhambra, Cal.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
McAlear Mfg. Co., 1949 S. Western Ave., Chicago 6, Ill.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., Spring Valley, N. Y.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue, Los Angeles 26, Calif.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Rensselaer Valve Co., Troy, N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
S. Morgan Smith Co., York, Pa.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.

RESIDUAL CHLORINE CONTROL APPARATUS

Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
LaMotte Chem. Co., Towson 4, Md.
W. A. Taylor & Co., 7300 York Rd., Baltimore, Md.
Wallace & Tiernan Co., Inc., Newark 1, N. J.

RUBBER LINED PIPE AND VALVES

American Hard Rubber Co., 11 Mercer St., New York 13, N. Y.

RUST PREVENTION

(Tanks, Pipe Lines, Submerged Metal)
Calgon, Inc., Hagan Bldg., Pittsburgh, Pa.
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago, Ill.
Electro Rust-Proofing Corp., 1026 Wayne Ave., Dayton 10, Ohio. (Cathodic Protection)
Inertol Co., Newark 5, N. J.
Johnston & Jennings Co., Rusta Restor Div., 877 Addison Rd., Cleveland, Ohio.
Philadelphia Quartz Co., Third & Ionic Sts., Philadelphia, Pa.
Walles Dove-Hermiston, Westfield, N. J.

SADDLES, PIPE

Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Dresser Mfg. Div., Bradford, Pa.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hays Mfg. Co., Erie, Pa.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., Spring Valley, N. Y.

SAMPLERS AND SAMPLING TABLES

Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Drake Mfg. Co., 1461 Belfield Ave., Philadelphia, Pa.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
F. B. Leopold Co., 422 First Ave., Pittsburgh, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.

SAND EXPANSION INDICATORS

Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Foxboro Co., Foxboro, Mass.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

SCALES, SLUDGE CONVEYOR

Builders-Providence, 9 Codding St., Providence, R. I.

SCALES, WEIGHING

Fairbanks-Morse Co., 600 S. Michigan Ave., Chicago 5, Ill.

SCREENINGS GRINDERS

(See Grinders)

SCREENS, INTAKE

Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 300 W. Pershing Rd., Chicago 9, Ill.
Yeomans Bros. Co., 1433 N. Dayton St., Chicago 22, Ill.

SCREENS, SAND, GRAVEL AND STONE

Allis-Chalmers Mfg. Co., Milwaukee 1, Wis.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.

SCREENS, SEWAGE

Allis-Chalmers Mfg. Co., Milwaukee 1, Wis.
American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Walker Process Equip. Co., Aurora, Ill.
Yeomans Bros. Co., 1433 N. Dayton St., Chicago 22, Ill.

SCREENS, VIBRATING

Allis-Chalmers Mfg. Co., Milwaukee 1, Wis.
Link Belt Co., 307 N. Michigan Ave., Chicago 1, Illinois.

SCREENS, WATER WELL

Layne & Bowler, Inc., P. O. Box 215, Hollywood Sta., Memphis 8, Tenn.

SEGMENT BLOCKS AND PIPE LINER PLATES (Vitrified)

Nat'l Clay Pipe Mfrs. Inc., 111 W. Washington St., Chicago, Ill.

SEPTIC TANKS (Vitrified Clay)

Nat'l Clay Pipe Mfrs., Inc., 111 W. Washington St., Chicago, Ill.

SERVICE BOXES

Central Foundry Co., 386 Fourth Ave., New York City.
Hays Mfg. Co., Erie, Pa.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., Spring Valley, N. Y.

SERVICE PIPE

Glauber Brass Mfg. Co., Kinsman, Ohio.

SEWAGE EJECTORS

(See Ejectors, Pneumatic.)

SEWAGE SAMPLERS

Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Drake Mfg. Co., 1461 Belfield Ave., Philadelphia, Pa.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
Omega Machine Co., 9 Codding St., Providence 1, R. I.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Inc., Newark, N. J.

SEWAGE SLUDGE INCINERATOR

Dorr Co., 570 Lexington Ave., New York City.
Morse Boulger Destructor Co., 216 East 45th St., New York City.
Nichols Engineering & Research Corp., 60 Wall Tower, New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

SEWER CLEANING EQUIP. AND SERVICE

Champion Corp., Hammond, Ind.
J. C. Fitzgerald, P. O. Box 280, Coral Gables 34, Fla.
Flexible Sewer-Rod Eqpt. Co., 9059 Venice Blvd., Los Angeles, Calif.
National Water Main Cleaning Co., 30 Church St., New York City.
W. H. Stewart, P. O. Box 767, Syracuse, N. Y.

SEWER ODOR PREVENTION

(See Chlorine)
Cloroben Corp., Jersey City, N. J.

SEWER PIPE

(See Pipe, Sewer)

SEWER PIPE JOINTS

Atlas Mineral Prod. Co., Mertztown, Pa.
Michael Hayman & Co., 870 E. Ferry St., Buffalo, N. Y.
Hydraulic Development Corp., 50 Church St., New York City.
Nat'l Clay Pipe Mfrs., Inc., 111 W. Washington St., Chicago, Ill.
L. A. Weston, Adams, Mass.

SEWER RODS

Flexible Sewer-Rod Eqpt. Co., 9059 Venice Blvd., Los Angeles, Calif.
W. H. Stewart, P. O. Box 767, Syracuse, N. Y.

SILENCERS, ENGINE, INTAKE, EXHAUST AND AIR INTAKE

Burgess-Manning Co., 2815 W. Roscoe, Chicago, Ill.

SIPHONS (Sewage)

American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City. (Alternating.)
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Yeomans Brothers Co., 1433 N. Dayton St., Chicago 22, Ill.

SLEEVES, PIPE REPAIR

Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Dresser Mfg. Div., Bradford, Pa.
Eddy Valve Co., Waterford, N. Y.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Northrop & Co., Inc., Spring Valley, N. Y.
Rensselaer Valve Co., Troy, N. Y.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., East Orange, N. J.
Warren Foundry & Pipe Corp., 11 Broadway, New York City.
R. D. Wood Co., Public Ledger Bldg., Independence Square, Philadelphia, Pa.

SLEEVES, TAPPING (Valve)

Eddy Valve Co., Waterford, N. Y.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg., Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Rensselaer Valve Co., Troy, N. Y.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., East Orange, N. J.
Vogt Brothers Mfg. Co., Louisville, Ky.

SLUDGE COLLECTORS

American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 West Adams St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Walker Process Equip., Inc., Aurora, Ill.
Yeomans Brothers Co., 1433 N. Dayton St., Chicago 22, Ill.

SLUDGE DISINTEGRATORS

Jeffrey Mfg. Co., Columbus, Ohio.
Royer Foundry & Mach. Co., 158 Pringle St., Kingston, Pa.

SLUDGE EJECTORS

(See Ejectors, Pneumatic.)

SLUDGE ELEVATORS, LIQUID

Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Hardinge Corp., York, Pa.

SLUDGE GAS ENGINES

(See Engines, Sludge Gas)

SLUDGE PUMPS

(See Pumps, Sludge)

SLUDGE SAMPLERS

Drake Mfg. Co., 1461 Belfield Ave., Philadelphia, Pa.

SNUBBERS

(See Silencers.)

SODA ASH

Diamond Alkali Co., Pittsburgh, Pa.
Hood Chemical Co., 450 W. 31st St., New York City.
Innis, Speiden & Co., 117 Liberty St., New York City.
Mathieson Alkali Works, 60 E. 42nd St., New York City.
Niagara Alkali Co., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.
Pittsburgh Plate Glass Co., Columbia Chemical Div., Grant Bldg., Pittsburgh 19, Pa.
E. M. Sergeant Pulp & Chemical Co., Inc., 7 Dey St., New York 7, N. Y.
Solvay Sales Corp., 40 Rector St., New York City.

SODIUM ALUMINATE

Dearborn Chemical Co., 310 Michigan Ave., Chicago, Ill.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia 7, Pa.

SODIUM BISULPHITE

General Chemical Co., 40 Rector St., New York, N. Y.

SODIUM CHLORITE

Mathieson Alkali Works, 60 East 42nd St., New York 17, N. Y.

SODIUM PHOSPHATES (Glassy)

Calgon, Inc., Hagan Bldg., Pittsburgh, Pa.

SODIUM SILICATE

Diamond Alkali Co., Pittsburgh, Pa.
General Chemical Co., 40 Rector St., New York 6, N. Y.
Philadelphia Quartz Co., Third & Ionic Sts., Philadelphia 6, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Standard Silicate Division, Diamond Alkali Co., Pittsburgh, Pa.

SOFTENERS

(See Water Softening Equipment)

SPEED REDUCERS, TRANSMISSION

De Laval Steam Turbine Co., Trenton, N. J.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Worthington Pump & Mach. Corp., Harrison, N. J.

SPRINKLING FILTER EQUIP.

American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
Lakeside Engrg. Corp., 222 West Adams St., Chicago, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Walker Process Equip., Inc., Aurora, Ill.
Yeomans Bros. Co., 1433 N. Dayton St., Chicago 22, Ill.

SPRINKLING FILTER UNDERDRAINS

(See Filter Underdrains, Sewage.)

STACKS

Cement Gun Co., P. O. Box 424, Allentown, Pa.
Chicago Bridge & Iron Co., 2198 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Dresser Industries, Inc., Cleveland 13, Ohio.
General American Process Equipment, 420 Lexington Ave., New York 17, N. Y.
Johns-Manville Co., 22 E. 40th St., New York City.
Nooter, John, Boiler Works Co., 1410 S. 2nd St., St. Louis 4, Mo.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Stacey Bros. Gas Construction Co., 5535 Vine St., Cincinnati 16, Ohio.

STANDPIPES

(See Tanks and Standpipes.)

STANDPIPE AND TANK PRESERVATION

(See Cathodic Protection Process.)

STERILIZING WATER MAINS

(See Water Main Sterilization)

STIRRERS (Laboratory)

Dorr Co., 570 Lexington Ave., New York City.
Omega Mach. Co., Inc., 9 Codding St., Providence 1, R. I.
Phipps & Bird, Inc., Sixth & Byrd Sts., Richmond, Va.

STOKERS

Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Johnston & Jennings Co., 877 Addison Rd., Cleveland, Ohio.
Link-Belt Co., 2410 W. 18th St., Chicago 8, Ill.
Westinghouse Electric & Mfg. Co., P. O. Box 868, Pittsburgh 30, Pa.

STORAGE TANKS (See Standpipes and Tanks)

STRAINERS, SUCTION

Barrett, Haentjens & Co., Hazleton, Pa.
Edson Corp., 49 D St., South Boston, Mass.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.

SULPHATE OF ALUMINA

(See Filter Alum)

SULPHUR DIOXIDE (Liquid)

Virginia Smelting Co., West Norfolk, Va.

SUPERNATANT LIQUOR (Selectors and Treaters)

Pacific Flush-Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

SWITCHBOARDS

Allis-Chalmers Mfg. Co., Milwaukee 1, Wis.
Clark Controller Co., 1146 E. 152nd St., Cleveland 10, Ohio.
Climax Engineering Co., Clinton, Iowa.
Johns-Manville, 22 East 40th St., New York, N. Y.
Westinghouse Electric & Mfg. Co., P. O. Box 868, Pittsburgh 30, Pa.

TANKS AND STANDPIPES (Steel)

Chicago Bridge & Iron Co., 2198 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
General American Process Equipment Div., 420 Lexington Ave., New York 17, N. Y.
Nooter, John, Boiler Works Co., 1410 S. 2nd St., St. Louis 4, Mo.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Stacey Bros. Gas Construction Co., 5535 Vine St., Cincinnati 16, Ohio.

TANKS, RUBBER LINED

Atlas Mineral Products Co., Mertztown, Pa.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Dorr Co., 570 Lexington Ave., New York City.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Nooter, John, Boiler Works Co., 1410 S. 2nd St., St. Louis 4, Mo.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Stacey Bros. Gas Construction Co., 5535 Vine St., Cincinnati 16, Ohio.
Wallace & Tiernan Co., Inc., Newark 1, N. J.

TAPPING MACHINES

Glauber Brass Mfg. Co., Kinsman, Ohio.
Hays Mfg. Co., Erie, Pa.
Mueller Co., Decatur, Ill.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., East Orange, N. J.

TASTE & ODOR REMOVAL CHEMICALS

Activated Alum Corp., Curtis Bay, Baltimore, Md.
American Norit Co., Jacksonville, Fla.
Cliffs Dow Chemical Co., Marquette, Mich.
Darco Corp., 60 E. 42nd St., New York 17, N. Y.
General Chemical Co., 40 Rector St., New York 6, N. Y.
Industrial Chemical Sales Div., West Virginia Pulp & Paper Co., Inc., 230 Park Ave., New York 17, N. Y.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
Mathieson Alkali Works, Inc., New York, N. Y.
Phelps Dodge Refg. Corp., 40 Wall St., New York, N. Y.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Virginia Smelting Co., West Norfolk, Va.
Wallace & Tiernan Co., Inc., Newark 1, N. J.

TESTERS (Water Meter)

Ford Meter Box Co., Wabash, Ind.
Hersey Mfg. Co., E and 2nd Sts., South Boston 27, Mass.
National Meter Division of Pittsburgh Equitable Meter Co., 4221 First Ave., Brooklyn, N. Y.
Neptune Meter Co., 50 W. 50th St., New York City.
Northrop & Co., Inc., Spring Valley, N. Y.
Peerless Pump Div., Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., East Orange, N. J.
Worthington-Gamon Meter Co., Newark, N. J.

TEST PLUGS (for Pipe)

Glauber Brass Mfg. Co., Kinsman, Ohio.
Richmond Fdry. & Mfg. Co., 1200 Hermitage Rd., Richmond, Va.

THICKENERS (Sludge)

Ralph B. Carter Co., 53 Park Place, New York City.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Yeomans Bros. Co., 1433 N. Dayton St., Chicago 22, Ill.

TOOLS, PIPE

(See Pipe Tools.)

TOOLS, PNEUMATIC

Davey Compressor Co., Kent, Ohio.
Jaeger Machine Co., 716 Dublin Ave., Columbus, Ohio.

TRAPS, DRIP, FLAME, SEDIMENT

Automatic Control Div., Climax Industries, 1949 S. Western Ave., Chicago, Ill.
Josam Mfg. Co., 1783 E. 11th St., Cleveland, Ohio.
McAlear Mfg. Co., 1949 S. Western Ave., Chicago 8, Ill.
Pacific Flush Tank Co., 4341 Ravenswood Ave., Chicago, Ill.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.

TRENCHING EQUIPMENT

Hydrauger Corp., Ltd., 116 New Montgomery St., San Francisco, Calif.

TRICKLING FILTER UNDERDRAINS

(See Filter Underdrains.)

TRITURATORS

(See also Grinders)
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.

TUNNEL LINER PLATES

Armco Drainage Prod. Assn., Middletown, Ohio.

TUNNEL MACHINERY, BORING & LINING

Jeffrey Mfg. Co., Columbus, Ohio.

TURBINES, HYDRAULIC

Allis-Chalmers Mfg. Co., Milwaukee 1, Wis.
De Laval Steam Turbine Co., Trenton, N. J.
Hunt, Rodney, Machine Co., Orange, Mass.
Morris Machine Works, Baldwinsville, N. Y.
S. Morgan Smith Co., York, Pa.

TURBINES, STEAM

Allis-Chalmers Mfg. Co., Milwaukee 1, Wis.
De Laval Steam Turbine Co., Trenton, N. J.
Morris Machine Works, Baldwinsville, N. Y.
Worthington Pump & Mach. Corp., Harrison, N. J.

VALVE BOXES

Central Foundry Co., 386 Fourth Ave., New York City.
Chapman Valve Mfg., Indian Orchard, Mass.
Eddy Valve Co., Waterford, N. Y.
Ford Meter Box Co., Wabash, Ind.
Hunt, Rodney, Machine Co., Orange, Mass.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Northrop & Co., Inc., Spring Valley, N. Y.
Rensselaer Valve Co., Troy, N. Y.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., Public Ledger Bldg., Independence Square, Philadelphia, Pa.

VALVE BOX LOCATORS

Northrop & Co., Inc., (Spring Valley, N. Y.)

VALVE OPERATOR

(See Gate Valve Operator)

VALVES

American Car & Fdy. Co., 30 Church St., New York 8, N. Y.
Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Armco Drainage Products Assn., Middletown, Ohio.
Automatic Control Div., Climax Industries, 1949 S. Western Ave., Chicago, Ill.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Clayton Mfg. Co., Alhambra, Calif.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Eddy Valve Co., Waterford, N. Y.
Golden-Anderson Valve Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Rodney Hunt Machine Co., Orange Mass.
Josam Mfg. Co., 1783 E. 11th St., Cleveland, Ohio.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
McAlear Mfg. Co., 1949 S. Western Ave., Chicago 8, Ill.
M. & H. Valve & Fittings Co., Anniston, Ala.
Merco Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.
Mueller Co., Chattanooga, Tenn.
Peerless Pump Div., Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Rensselaer Valve Co., Troy, N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., East Orange, N. J.
S. Morgan Smith Co., York, Pa.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.
Vogt Bros. Mfg. Co., Louisville, Ky.
R. D. Wood Co., Public Ledger Bldg., Independence Square, Philadelphia, Pa.

VALVES, AIR RELEASE

Chapman Valve Mfg. Co., Indian Orchard, Mass.
Eddy Valve Co., Waterford, N. Y.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
McAlear Mfg. Co., 1949 S. Western Ave., Chicago 8, Ill.
Northrop & Co., Inc., Spring Valley, N. Y.
Rensselaer Valve Co., Troy, N. Y.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
Valve and Primer Corp., Chicago 2, Ill.
R. D. Wood Co., Public Ledger Bldg., Independence Square, Philadelphia, Pa.

VALVES, AIR & VACUUM

Automatic Control Div., Climax Industries, 1949 S. Western Ave., Chicago, Ill.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Clayton Mfg. Co., Alhambra, Calif.
Dresser Industries, Inc., Cleveland 13, Ohio.
Eddy Valve Co., Waterford, N. Y.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
McAlear Mfg. Co., 1949 S. Western Ave., Chicago 8, Ill.
Northrop & Co., Inc., Spring Valley, N. Y.
Rensselaer Valve Co., Troy, N. Y.
Roots-Connersville Blower Corp., Connersville, Ind.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
Valve and Primer Corp., Newark 1, N. J.
R. D. Wood Co., Public Ledger Bldg., Independence Square, Philadelphia, Pa.

VALVES, ALTITUDE

Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Automatic Control Div., Climax Industries, 1949 S. Western Ave., Chicago, Ill.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Clayton Mfg. Co., Alhambra, Calif.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
McAlear Mfg. Co., 1949 S. Western Ave., Chicago 8, Ill.
Northrop & Co., Inc., Spring Valley, N. Y.
R-S Products Corp., Philadelphia 44, Pa.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
Rensselaer Valve Co., Troy, N. Y.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
S. Morgan Smith Co., York, Pa.
Valve and Primer Corp., Newark 1, N. J.

VALVES, BUTTERFLY

Allis-Chalmers Mfg. Co., Milwaukee 1, Wis.
Automatic Control Div., Climax Industries, 1949 S. Western Ave., Chicago, Ill.
Hunt, Rodney, Machine Co. Orange, Mass.
Ludlow Valve Mfg. Co., Troy, N. Y.
R-S Products Corp., Philadelphia 44, Pa.

VALVES, CHECK

Automatic Control Div., Climax Industries, 1949 S. Western Ave., Chicago, Ill.
Barrett, Haentjens & Co., Hazleton, Pa.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Clayton Mfg. Co., Alhambra, Calif.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Eddy Valve Co., Waterford, N. Y.
Golden-Anderson Valve Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hersey Mfg. Co., E and First Sts., South Boston 21, Mass.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Josam Mfg. Co., 1783 E. 11th St., Cleveland, Ohio
Ludlow Valve Mfg. Co., Troy, N. Y.
McAlear Mfg. Co., 1949 S. Western Ave., Chicago 8, Ill.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Northrop & Co., Inc., Spring Valley, N. Y.
Rensselaer Valve Co., Troy, N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., East Orange, N. J.
S. Morgan Smith Co., York, Pa.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.
R. D. Wood Co., Public Ledger Bldg., Independence Square, Philadelphia, Pa.

VALVES, CHLORINE

Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Wallace & Tiernan Co., Inc., Newark 1, N. J.

VALVES, CONE

American Car & Fdy. Co., 30 Church St., New York 8, N. Y.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Merco Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.
Peerless Pump Div., Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Rensselaer Valve Co., Troy, N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
S. Morgan Smith Co., York, Pa.

VALVES, DIAPHRAGM

McAlear Mfg. Co., 1949 S. Western Ave., Chicago 8, Ill.

VALVES, ELECTRICALLY OPERATED

(See Valves, Motor Operated.)

VALVES, EMERGENCY TRIP

Clayton Mfg. Co., Alhambra, Calif.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Ross Valve Mfg. Co., Troy, N. Y.

VALVES, FLAP

Chapman Valve Mfg. Co., Indian Orchard, Mass.
Eddy Valve Co., Waterford, N. Y.
Golden-Anderson Valve Spec Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Josam Mfg. Co., 1783 E. 11th St., Cleveland, Ohio.
Ludlow Valve Mfg., Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Rensselaer Valve Co., Troy, N. Y.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., Public Ledger Bldg., Independence Square, Philadelphia, Pa.

VALVES, FLOAT

Chapman Valve Mfg. Co., Indian Orchard, Mass.
Clayton Mfg. Co., Alhambra, Calif.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh,
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
McAlear Mfg. Co., 1949 S. Western Ave., Chicago 8, Ill.
Northrop & Co., Inc., Spring Valley, N. Y.
Rensselaer Valve Co., Troy, N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
S. Morgan Smith Co., York, Pa.

VALVES, FOOT

Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Eddy Valve Co., Waterford, N. Y.
Edson Corp., 49 D St., South Boston, Mass.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
Mueller Co., Chattanooga, Tenn.
Northrop & Co., Inc., Spring Valley, N. Y.
Rensselaer Valve Co., Troy, N. Y.
Vogt Bros. Mfg. Co., 1402 W. Main St., Louisville 3, Ky.
R. D. Wood Co., Public Ledger Bldg., Independence Square, Philadelphia, Pa.

VALVES, FOUR WAY

American Car & Fdy. Co., 30 Church St., New York 8, N. Y.
Clayton Mfg. Co., Alhambra, Calif.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
F. B. Leopold Co., Inc., 422 First Ave., Pittsburgh, Pa.
Merco Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.
Peerless Pump Div., Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Roberts Filter Mfg. Co., Darby, Pa.

VALVES, GATE

Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Eddy Valve Co., Waterford, N. Y.
Rodney Hunt Machine Co., Orange, Mass.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Rensselaer Valve Co., Troy, N. Y.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., East Orange, N. J.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., Public Ledger Bldg., Independence Square, Philadelphia, Pa.

VALVES, HYDRAULIC CYLINDER OPERATED

American Car & Fdy. Co., 30 Church St., New York 8, N. Y.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Eddy Valve Co., Waterford, N. Y.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Hunt, Rodney, Machine Co., Orange, Mass.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Merco Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.
Mueller Co., Chattanooga, Tenn.
Peerless Pump Div., Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Rensselaer Valve Co., Troy N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., East Orange, N. J.
S. Morgan Smith Co., York, Pa.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., Public Ledger Bldg., Independence Square, Philadelphia, Pa.

VALVES, LUBRICATED PLUG

American Car & Fdy. Co., 30 Church St., New York 8, N. Y.
Merco-Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.

VALVES, MOTOR OPERATED

American Car & Fdy. Co., 30 Church St., New York 8, N. Y.
Automatic Control Div., Climax Industries, 1949 S. Western Ave., Chicago, Ill.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Eddy Valve Co., Waterford, N. Y.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Hunt, Rodney, Machine Co., Orange, Mass.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
McAlear Mfg. Co., 1949 S. Western Ave., Chicago 8, Ill.
Merco Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.
Mueller Co., Chattanooga, Tenn.
Peerless Pump Div., Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Rensselaer Valve Co., Troy, N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., East Orange, N. J.
S. Morgan Smith Co., York, Pa.
R. D. Wood Co., Public Ledger Bldg., Independence Square, Philadelphia, Pa.

VALVES, MUD AND PLUG

American Car & Fdy. Co., 30 Church St., New York 8, N. Y.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Eddy Valve Co., Waterford, N. Y.
Rodney Hunt Machine Co., Orange Mass.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
Merco Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Peerless Pump Div., Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Rensselaer Valve Co., Troy, N. Y.
Roberts Filter Mfg. Co., Darby, Pa.
Vogt Brothers Mfg. Co., Louisville, Ky.

VALVES, PRESSURE REDUCING

Automatic Control Div. Climax Industries, 1949 S. Western Ave., Chicago, Ill.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Clayton Mfg. Co., Alhambra, Calif.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Hays Mfg. Co., Erie, Pa.
McAlear Mfg. Co., 1949 S. Western Ave., Chicago 8, Ill.
Johnston & Jennings Co., 877 Addison Rd., Cleveland, Ohio.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., Spring Valley, N. Y.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Rensselaer Valve Co., Troy, N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
S. Morgan Smith, York, Pa.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.

VALVES, RELIEF

Automatic Control Div., Climax Industries, 1949 S. Western Ave., Chicago, Ill.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Clayton Mfg. Co., Alhambra, Calif.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Hays Mfg. Co., Erie, Pa.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Johnston & Jennings Co., 877 Addison Rd., Cleveland, Ohio.
McAlear Mfg. Co., 1949 S. Western Ave., Chicago 8, Ill.
Ludlow Valve Mfg. Co., Troy, N. Y.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., Spring Valley, N. Y.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Rensselaer Valve Co., Troy, N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
S. Morgan Smith Co., York, Pa.
Valve and Primer Corp., Newark 1, N. J.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.

VALVES, RUBBER, GLASS AND LEAD LINED

American Hard Rubber Co., 11 Mercer St., New York 13, N. Y.
Automatic Control Div., Climax Industries, 1949 S. Western Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Johns-Manville, 22 E. 40th St., New York, N. Y.
S. Morgan Smith, York, Pa.

VALVES, SPECIAL, AUTOMATIC (Including Remote Control.)

Barrett, Haentjens & Co., Hazleton, Pa.
Clayton Mfg. Co., Alhambra, Calif.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa.
McAlear Mfg. Co., 1949 S. Western Ave., Chicago 8, Ill.
Northrop & Co., Inc., Spring Valley, N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
Rensselaer Valve Co., Troy, N. Y.
S. Morgan Smith Co., York, Pa.
A. P. Smith Mfg. Co., 595 N. Arlington Ave., E. Orange, N. J.

VALVES, WATER METER SPECIAL

Ford Meter Box Co., Wabash, Ind.

VARIABLE SPEED TRANSMISSIONS

Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Omega Machine Co., 9 Codding St., Providence 1, R. I.

VENTURI TUBES

Bailey Meter Co., 1072 Ivanhoe, Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St. Providence, R. I.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Foxboro Co., Foxboro, Mass.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
Leupold & Stevens Instruments, 4445 N. E. Glisan St., Portland, Ore.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

VIBRATING SCREENS (Liquid)

Link Belt Co., 307 N. Michigan Ave., Chicago 1, Ill.

VIBRATORS, ELECTRO-MAGNETIC

Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.

VISES, PIPE

Ridge Tool Co., Elyria, Ohio.

VITRIFIED CLAY PIPE AND PRODUCTS

Nat'l Clay Pipe Mfrs., Inc., 111 W. Washington St., Chicago, Ill.

WASTE GAS BURNERS

Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.

WATER ANALYSIS EQUIPMENT AND REAGENTS

(See Laboratory Apparatus and Reagent.)

WATER HAMMER ARRESTERS

Josam Mfg. Co., 1783 E. 11th St., Cleveland, Ohio.
S. Morgan Smith Co., York, Pa.

WATER MAIN STERILIZATION (A Service)

Wood and Preuit, 1740 K St., N.W., Washington, D. C.

WATER LEAK, LOCATING INSTRUMENTS

Fisher Research Lab., 1961-63-65 University Ave., Palo Alto, Calif.
Northrop & Co., Inc., Spring Valley, N. Y.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

WATER LEVEL CONTROL

Automatic Control Corp., 1013 University Ave., St. Paul 4, Minn.
B/W Controller Corp., Birmingham, Mich.

WATER LEVEL RECORDERS

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Foxboro Co., Foxboro, Mass.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
R. W. Sparling, Box 3277 Terminal Annex, Los Angeles, Calif.

WATER MAIN CLEANING

Flexible Underground Pipe Cleaning Co., 9059 Venice Blvd., Los Angeles, Calif.
National Water Main Cleaning Co., 30 Church St., New York 7, N. Y.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Geo. H. Werfelman Co., Los Angeles, Cal.

WATERPROOFING PAINTS, COMPOUNDS AND MATERIALS

Dearborn Chemical Co., 310 S. Michigan Ave., Chicago, Ill.
General Paint Corp., Cleveland, O.
Inertol Co., Newark 5, N. Y.
Johns-Manville, 22 E. 40th St., New York City.
Wailes Dove-Hermiston, Westfield, N. J.

WATER SOFTENING CHEMICALS AND COMPOUNDS

(See Individual Chemicals for Water Purification and Softening)

WATER SOFTENING EQUIPMENT

Allis-Chalmers Mfg. Co., Milwaukee 1, Wis.
American Well Works, Aurora, Ill.
Belco Ind. Equip. Div., 50 Iowa Ave., Patterson 3, N. J.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Chem-Feeds-Inc., 77 Reservoir Ave., Providence, R. I.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Dorr Co., Inc., 570 Lexington Ave., New York City.
Everson Mfg., Co., 214 W. Huron St., Chicago, Ill.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Lapp Insulator Co., Le Roy, N. Y.
F. B. Leopold Co., Inc., 422 First Ave., Pittsburgh, Pa.
Link Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Liquid Conditioning Corp., Linden, N. J.
Nooter, John, Boiler Works Co., 1410 2nd St., St. Louis 4, Mo.
Omega Machine Co., 3409 E. 18th, Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Walker Process Equip., Inc., Aurora, Ill.
Wallace & Tiernan Co., Inc., Newark, N. J.
Worthington Pump & Mach. Corp., Harrison, N. J.
Zeolite Chemical Co., 140 Cedar St., New York 6, N. Y.

WATER STABILIZATION (Chemicals for)

Dearborn Chemical Co., 310 S. Michigan Ave., Chicago, Ill.
Calgon, Inc., Hagan Bldg., Pittsburgh, Pa.

WATER SUPPLY CONTRACTORS

(See Contractors)

WATER TREATMENT FOR SCALE AND CORROSION

Allis-Chalmers Mfg. Co., Milwaukee 1, Wis.
Belco Ind. Equip. Div., 50 Iowa Ave., Patterson 3, N. J.
Calgon, Inc., Hagan Bldg., Pittsburgh, Pa.
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago, Ill.
General Chemical Co., 40 Rector St., New York 6, N. Y.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago, Ill.
Liquid Conditioning Corp., Linden, N. J.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Zeolite Chemical Co., 140 Cedar St., New York 6, N. Y.

WATER TREATMENT PLANTS (Steel)

Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

WATER WASTE SURVEYS

Pitometer Co., 50 Church St., New York City.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

WELLS, COMPLETE

Layne-Bowler, Inc., P. O. Box 215, Hollywood Sta., Memphis 8, Tenn.

WIND VANES AND INDICATORS

M. C. Stewart, Ashburnham, Mass.

WRAPPING, PIPE

(See Pipe, Wrapping)

WRENCHES, REVERSIBLE RATCHET

Dresser Mfg. Co., Bradford, Pa.

WROUGHT IRON (Pipe, Gates, Bars, Etc.)

A. M. Byers Co., Clark Bldg., Pittsburgh, Pa.

ZEOLITE AND ZEOLITE SOFTENERS

Belco Ind. Equip. Div., 50 Iowa Ave., Patterson 3, N. J.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
Lakeside Engrg. Corp., 222 West Adams St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Roberts Filter Mfg. Co., Darby, Pa.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Worthington Pump & Mach. Corp., Harrison, N. J.
Zeolite Chemical Co., 140 Cedar St., New York 6, N. Y.

REFORESTATION ON MUNICIPAL WATER WORKS LANDS*

By W. R. LaDue

Supt. and Chief Engr., Bureau of Water and Sewerage, Akron, O.

IN 1825, in the County of Summit, the City of Akron was incorporated. In seventy-five years it found itself a center of the cereal and reaper industries and by 1910 it had attained a population of 69,000 and became, at the beginning of the automobile age, the founder of an allied industry—the new rubber industry. Water was a problem, not particularly for industry, but because of domestic shortcomings. The growing city in April, 1912, purchased the private water company's holdings and embarked upon the water supply business as sole owner and operator.

The engineers retained by the city to study the water supply recommended the development of the Cuyahoga River at a suitable location fifteen miles northeast of Akron, above which point the river had accumulated a watershed of 206 square miles.

By this development the Akron Water Works embarked upon a career of land ownership which is the basis of the present story. Lake Rockwell, the City's impounding reservoir, consists of 750 acres of water surface and about 1750 acres of protective surrounding shore area. The latter had been farming land consisting of fairly well balanced tillable soil, grazing areas and woods. Forest areas of course had been long-since divested of marketable timber so that with few exceptions, there remained only second growth, third growth and even "slashings." For several years the new supply organization exerted most of its effort to supplying more and more water for the rapidly growing city, which by 1920 had acquired a population of 206,000. In the reservoir development the shoreline had been cleared to an elevation ten feet above flow line. Real planned development of the excess area began about 1922 when protective measures required the purchase of an adjacent fruit farm covering about fifty acres.

*This article is a slightly abridged version of the first of two articles on Land Use and Management by the author in the June, 1945, issue of *Water Works & Sewerage*.

Reforestation

Over and above the problem of use of orchard areas, there remained some 1600 acres of shore lands to be considered. These had been originally farms of varying degrees of diversity and usefulness. In considering the treatment of these areas, the requirements of water supply were paramount. It was realized that around and above any reservoir, the conditions of the soil, cultivation, geologic formations, grazing and forest cover, all contribute to the quality of the water reaching the reservoir. In our case, restoration of forest cover seemed to offer the answer.

The native covering of tree growth, found upon any landscape defines, in the broad sense, forestation. Reforestation is the restoration, by man or nature of that which man or other causes has removed. In all forested areas a certain amount of water content is removed from the soil by transpiration through plant life and trees. This may appear as a debit but any depleting effect is offset many times by the prevention of soil erosion with resultant silting of reservoirs; flood reduction through retardation; the development of soils and the actual ground storage of waters. Shore protection appeared essential and forest cover presented a source of real control of human activities and an effective means of sanitary protection.

Full Use of Native Flora

A physical survey of the area disclosed eroded areas, "slashings," native forest, scrub cover, old plow lands, swamps and bogs. Some areas would not support tree growth so that a study of the native flora species proved valuable, especially in the light of the purpose and end point of the operation. In slightly moist areas, larch proved excellent. For erosion control locust and honeysuckle were effective and particularly hardy. As a ground builder and ground cover the quicker growing varieties of evergreens were selected. The value of a mat of pine needles in the retention of moisture and in subsequent soil building is well known. Where woods existed and for color control it appeared essential to keep deciduous tree leaves out of the water, a dense screen of evergreens was planted along the reservoir shore between the deciduous growth and the water. This accepts the theory that evergreens will catch, entrap and retain the falling leaves.

Forestry Methods

A survey of native predominant species disclosed maple, elm, walnut, chestnut (now gone), oak, dogwood, beech and tamarack. Proximity of the reservoir rather limited reforestation species to the several varieties of pines. For barren soils, including "borrowpits," jack pines were ideal; for ornamental effects, arbor-vitae, Norway and Blue spruce proved satisfactory; for general cover, Scotch, Austrian, Corsican, red and native white pines were effective. At the request of the Forestry Division, we have experimented also with southern pine, western spruce and pitch pine, with varying results. There were of course

Signs of Spring—Akron's Planting Crews Are Out.
Note paired two-man teams—shovel man and planter. One man has just brought up a bucket of "mudded" transplants. Close-up of mudding operations appears further on.)

The Beginning of a Nursery

3-Year-Old Nursery Ready for Tapping

exceptions where small areas were eventually planted with walnuts, tulip, maple and locust. We made our first planting of any consequence in the spring of 1922 using mixed pines.

It should be related that the advice and experience of the Ohio State Division of Forestry and that of the Federal Government have proved of immense value and are free for the asking. Such advice should be sought and followed.

The State of Ohio maintains several nurseries in which thousands of seedlings of many varieties are produced annually. Throughout the 23 years since 1922 these seedlings have been secured in quantities up to 200,000 per year. The price is nominal where public reforestation is the established purpose.

Methods of Planting and Transplanting

Planting agencies have used two methods for the transplanting of seedlings from nursery stock. The first involves planting direct in permanent and final location. Due to the tenderness of the two to three year old seedlings, handling in rough territory, transportation and planting in general, this method produces a high rate of mortality. In some instances, this may mean little in final results if the losses are scattered. However, a difficult terrain may still indicate the necessity for use of this method. Our experience has lead us to accept the second method, that of purchasing one, two or three year old seedlings, transplanting them in our own nurseries until they are large enough for transfer to final location. In general, water supply practice has adopted this method. Depending upon the species this may require from two to four years before final transplanting is effective and conducive to good results.

Nursery and Its Importance

The selection of the nursery site is important. It should be the best soil available, equal to that required for a good vegetable garden, well worked, drained and fertilized. Since the tree is a crop, a rich soil produces a good crop and vice versa. Fertilization and plowing in the fall produces the best soil for spring harrowing and planting. Seedlings are ordered in late summer for delivery the following spring. We are usually notified a week in advance of the date when the seedlings are ready for delivery at the State Nursery. They are removed, moistened, wrapped in bundles of 1000 in peat moss and boxed for delivery. So far as handling of pines is concerned, we have drilled our men with this one slogan: "*Never* allow the roots to dry." This principal is basic and never-to-be-questioned.

Since many thousands are handled we have adopted the practice of "heeling in" the seedlings in soft ground upon receipt at our nursery. The bundles are broken and the seedlings placed in shallow trenches in moist earth, where they are covered loosely with the peat moss and earth. If left in bundles heating will occur with resultant moulding and irreparable damage to the roots. The young trees as "heeled in" may be watered from time to time until set out in the new nursery.

The spacing of the young trees in the nursery will of course vary. Species of tree, soil character and cultivation methods will dictate. Our current practice is to place seedlings two to three inches on center in rows two feet apart. A trench about four inches deep is prepared in damp (not wet) soil and the seedlings transferred on a planting board. Several steps are involved. First a hole about two feet in diameter and one foot deep is excavated, in which a rather "sloppy" mud is prepared. Seedlings from the "heeled-in" rows are removed in bunches of 75 to 100 and their roots thoroughly smeared in the mud bath; being removed a few at a time to a table where they are placed on the planting boards immediately before planting in the nursery rows. Upon removal from the boards, the earth is pressed firmly against the roots and the parts above ground straightened. A nursery planting crew consists of five men—a "mudder" who prepares the planting boards; a "carrier" who delivers the boards to the planters and also keeps the "mudder" supplied with properly prepared seedlings; two "planters", one to plant the trees and the other to fix the final set; and one "digger" who prepares the rows in advance of the "planters". Throughout the process, the slogan—"*Never* allow the roots to dry"—is strictly followed. Several crews may be employed at the same time on different areas where the number of seedlings involved is large. Varieties are never mixed in the nursery, due to different growing characteristics.

Soil conditions will determine the nature of cultivation. In sandy soils, it is possible to cultivate as often as is necessary to keep down weed growth without disturbing the roots of the seedlings. In heavier soils, this

Boxes of Transplants from Nursery, Ready for "Mudding" and Planting

Some 7-Year-Old Scotch Pine on Mogadore Watershed

is not possible without risking damage. Light depth cultivation to kill weeds is sufficient. We have purposely selected nurseries in sandy loam. Even so we have, after experimentation, adopted the policy of no cultivation, allowing the young trees and weeds to grow together naturally. Trial patches using both strict cultivation and no cultivation have indicated better results from no cultivation. In Ohio we have learned that weed growth can be of great value in protecting young trees from the direct rays of the hot summer sun.

Final Transplanting

In final plantings, selection of species depends upon the soil conditions and characteristics at the site. An attempt is always made to determine and use the best species available, as hereinbefore mentioned. We experimented with both fall and spring planting. Here again, the advice of State and Federal authorities proved valuable. Type of soil, species of tree and climate were of prime consideration. For our purpose, we have adopted spring planting as standard. It fits in better with the more advantageous use of our labor personnel; in spring the ground is more moist and more easily worked; there is little danger of roots drying out; it coordinates more closely with nursery practice, and it obviates danger of loss through frost upheaval.

Seedlings are left in our nursery for two or three years and, for certain varieties as long as four years. Rate of growth dictates. Red and Scotch pines grow the faster; spruce, southern and white pines the slower. It has been our experience with older transplants, that the roots become interlaced and entangled, so that removal is difficult without damage. Older trees are not so liable to survive disturbance. Two years also proved the best transplant age for several varieties of deciduous trees such as oak, maple, walnut and tulip. Locust root sprouts are transferred any time. Best results were obtained from planting "stratified" walnuts direct as seed. Several hundred hybrid chestnuts were transplanted direct from commercial nursery stock. These were carefully protected by rabbit guards and have thrived nicely. Rabbits and mice proved a nuisance among nursery seedlings and necessitated the use of poison.

In the transplanting of evergreens, several steps are involved quite similar to the initial handling of seedlings as above described. The transplants are removed by carefully loosening the earth and then immediately submerging the young tree roots in the "mud-hole". If the planting area is

A "Mud-Hole"
(An important operation is the "mudding" of transplants promptly after lifting from nursery and preparatory to hauling to the planting site.)

considerable distance from the nursery, lethal drying of the roots may result unless they are well protected by placing in containers and the roots well covered with moist earth. For this purpose we use wooden boxes, 20 by 20 by 16 inches deep, affording sufficient space for 400 to 800 trees, depending upon age and variety.

At the distant site, transportation and planting difficulties may necessitate "heeling in" and caring for as previously described. In any event, as close to planting time as possible, the roots of the transplants should receive protection against drying by the "mudhole" treatment. "Mudded" trees are transported in buckets to the planters where one man prepares the hole while the other plants. A crew is usually four men—one "mudder"; one "carrier" and two "planters". The holes will vary with the species, some having longer or wider root growth. In general, the hole should provide well loosened soil to surround the roots without crushing. Well-organized crews, in our experience, in fairly open areas, can average 400 to 600 trees per man per eight-hour day.

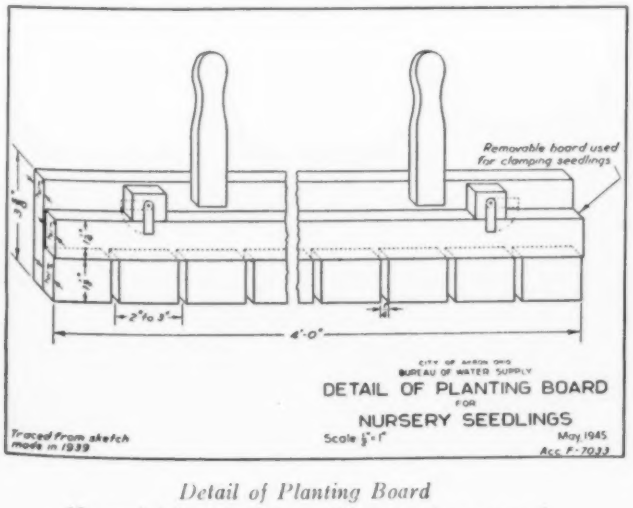
Tree Spacing

Spacing of trees depends upon the results desired and upon the species involved. Here forestry methods, advised by State and Federal agencies should be followed. For quick cover and complete eradication of competitive ground cover, plantings as close as 6 by 6 feet (1200 per acre) may be used. If timber is ultimately desired, such close planting, with subsequent trimming, after many years, will prevent the development of low branches. Long, straight trunks with best saw timber value will result. At our Lake Rockwell plantings, we started out with spacings 6 by 6 feet, later increasing this to 7 by 7 feet and now we are of the opinion that 8 by 8 or 8½ by 8½ (680 to 600 per acre) is ideal for plantings around reservoirs for all-over usefulness.

Hazards and Preparedness

Forest fires are a potential menace to reforestation. To guard against this hazard constant patrolling by the general reservoir patrolmen is required. Each of our patrolmen carries with him at all times in his car two five-gallon capacity filled portable water containers with hand-operated pump, and spray nozzle. In the past twenty years, these have proved their worth many times in subduing fires through early contact. Fire lanes of generous width (over 100 ft.) are provided between plantings in open areas. These lanes are bush-free and are mowed at least twice per year where topography will allow. Where plantings are adjacent to traveled roads, fire lanes are kept free from weed growth by frequent plowings during the year. Lookout towers are a necessity for adequate patrol. Access roads have been built entirely around our reservoir, not too far back from the water's edge, to permit easy access. Branch roads lead to the more remote areas. In constructing these roads, cinders from our power plant provide excellent road material for an all-year-around surface. Because such roads afford vistas of exceptional beauty, it is to be regretted that the public cannot be given access. Such practice, however, is neither conducive to safety from fire hazards, nor to satisfactory sanitary control. Reservoir patrol can definitely become a vital part in successful forest fire patrol.

Next to forest fires, blight is the greatest potential hazard to forestation. No absolute protection is possible; we can only strive for control. The stunting of growth, the reduction in the desirability of the ultimate product and the actual killing of the tree are but three results of tree disease. We have witnessed some tragic examples of tree blight in the passing of the chestnut and in the ravages of elm disease and the white pine blister rust. We have however, had gratifying results with the Chinese hybrid species of chestnut, which have somehow acquired immunization. We are



Detail of Planting Board
(So useful for planting seedlings in the nursery.)

The Planting Board in Use
(Showing how the board serves to get the seedlings uniformly spaced and at proper depth.)

Mixed Pines Seventeen Years Old

not attempting to propagate elms but the hardy "swamp" elm has as yet been little affected by blight. To control and protect our white pines from rust we have enjoyed the close cooperation of the State Forestry Division in eradication of currants and gooseberries (Ribes) which appear as important members of the "host" cycle. Fortunately, to date, our white pine stands have thrived very well indeed.

Fungus diseases may be controlled by fungicides and care in pruning. Careless logging or felling of trees against remaining growth often produces wounds which leave the tree at the mercy of decay. "Slashed" or carelessly logged areas are invitations to fire, insects and disease.

In well-established stands, animals cause little permanent damage. A natural balance is ultimately established between small game such as rabbits and groundhogs and the predatory fox. Bird life abounds. Wild duck and geese use our lake as a part of re-established migratory lane and its waters to rear their young. In fact we have one pair of eagles that have nested for years near a small swamp area. Deer are appearing in increasing numbers due to forest cover and protection.

Lake Rockwell Plantings

Using the methods outlined above, we have set out over 600,000 trees at Lake Rockwell in the period beginning in 1922 and including the spring of 1945. True, we have used a preponderance of pines of the several varieties but we have also made creditable plantings of oak, tulip, walnut and maple. When bank wash and erosion proved unsightly, willows were planted with quick satisfactory results. Where there remained fairly satisfactory natural cover our activities have been given to clearing and replacement in kind. In general, we have described acreage planting. For ornamental landscaping we have of course resorted to "spot" plantings, particularly along the shore line, on promontories, high points and bays. Arbor vitae, Norway and blue spruce, dogwood and wild crab have proven very effective and afford a pleasing appearance. We believe that increased air travel of the future will appreciate bulk landscaping, planted with the sky-view in mind. We maintain a nursery to facilitate "fill in" planting and for transfer to lands on our other reservoir areas. In the interest of variety and a continuing eventual timber crop, we have "skip" planted areas anticipating eventual fill-in. To our satisfaction, natural seeding has taken place from some of the older plantings. In mowing, these seedlings are guarded carefully.

Equipment

One of the really interesting things about forestation is the small amount of equipment involved. Outside of the plow and harrow to prepare nurseries, the only tools needed are spades, shovels, buckets, boxes, seedling tables, planting boards and a small pick-up truck. The hauling of water may be necessary in the more remote areas. This would require water barrels or drums. All these are found in any water works. Surely no operation of so great importance can be carried out with so little investment for equipment. Even the seedlings at the State Nursery, costing $1.00 to $4.00 per thousand (averaging $2.50), would amount to only $2,500 per million—enough trees, counting fire lanes and roads, to cover over 2,000 acres, equivalent to a little better than one dollar per acre.

Personnel

As mentioned, we in Ohio prefer spring planting, which can be started in March, as soon as the ground has passed from the muddy stage, and can be carried through until late May. In backward seasons, we have planted in June with good results. Ordinarily, for labor crews this type of work becomes an acceptable interlude between winter activities and the start of spring and summer construction. It is seldom that important work interferes and, of course, such work should not suffer. The men like such a change and look forward to it. We have employees who have participated in tree planting each year for over 20 years. During depression years such work offered a maximum of man-hours with a minimum of expense for equipment and material. Fortunately for WPA activities, we had a backlog of thousands of seedlings in our nurseries during this period and transferred thousands of transplants to our reservoir lands. It proved to be good, healthy, profitable work with far-seeing results. We have maintained sizable nurseries for postwar, "just in case". In any event, there is no postwar program which offers more in the development of a natural resource.

Costs

Again we believe forestation offers much in the way of very worth while development at low cost. For acreage plantings, assuming seedlings at $2.50 per thousand and average common labor at 75c per hour (50c to 90c) we have the following average unit costs:

Costs per 1,000 Seedlings

Seedlings	$ 2.50
Transportations from state nursery	1.00
Transplanting in nursery	6.00
Care in nursery	0.50
Planting in final location	15.00
Equipment and truck	1.50
Supervision	3.00
*Losses, conting., etc. (20% approx.)	5.50
Total cost per 1,000	$35.00

*It is of interest to record here that our losses have not been 10% in transferring from our nursery to final location.

Other Reservoirs

Prior to 1929 about 500 acres of land had been purchased in the upper valley of the Cuyahoga River 50 miles northeast from Akron, in an area known as East Branch. During the depression years, this area was projected into a reservoir area by the purchase of an additional 1,000 acres. Under a PWA contract about 600 acres were cleared, a public road raised and a rolled earth dam and spillway constructed. By 1939 this created a lake, having a water surface of 450 acres and a shore area of 1,050 acres, to augment domestic supply. Provision for reforestation was started at once by the creation of a small nursery maintained at about 20,000 seedlings. From 5,000 to 10,000 transplants per year have been set out in shore areas. In the spring of 1945 the nursery has been augmented by 38,000 seedlings.

In the depression year 1935-36 when it was indicated that work relief was necessary, the Water Department purchased about 2,750 acres of land about 8 miles east of Akron in the valley of the Little Cuyahoga River. By the clearing of about 1,200 acres, the reconstruction of a public highway and the building of an earthen dike and rolled earth dam, a lake of 1,000 acres was created as an industrial water supply, known as the Mogadore Reservoir. This work was done almost entirely by WPA labor and methods, thus affording work relief to as many as 2,000 men at one peak time. This reservoir was filled by early 1939. Excellent opportunities for reforestation activities (as described hereinbefore) were presented and accepted. A nursery of over 150,000 seedlings was established during the first year of construction—1937. Two years later, transplants were available for handling by relief labor. In the interim (1937-1939) transplants were secured to the extent of some 50,000 from Lake Rockwell nurseries. This use of a nursery, well-stocked by previous planning, shows what can be done in reforestation planning.

Postwar

Now is the time to establish nurseries if we are to receive maximum results in a field of public endeavor which bids well to receive nation-wide enthusiastic reception. The following excerpt is made from an editorial appearing in the *Cleveland Plain Dealer* issue of March 19, 1945:

"The Legion Joins Up"

"The conservation movement in Ohio gains a powerful and welcomed ally with the inauguration of a reforestation program by the Ohio department of the American Legion.

"The decision of this veterans' organization to join the battle for restoration of the state's most vital natural resources—soil, water and trees—was made quietly some months ago.

The Legion reveals to the uninitiated reader the extent to which conservation can be made to pay almost immediate as well as long-range dividends to the people of Ohio—and to all the people whether urban or rural residents.

"Fully aware that conservation calls for numerous measures, both public and private in nature, the Ohio American Legion has decided to place its emphasis on **reforestation.**

"We hope its action will inspire many other influential organizations to join actively in this movement which has as its purpose the preservation and restoration of the great natural resources which have been the physical foundation of the American way of life."

In 1922, the public evinced very little interest in "tree-planting". Reforestation programs received meager support and, in some instances, actual opposition arose. Today reforestation has become one of the most popular of conservation efforts. It must be more than an effort; it is a national necessity for the future.

PUBLIC RELATIONS IN WATER AND SEWAGE TREATMENT PLANTS

By WALTER A. SPERRY, Supt.
Aurora Sanitary District, Aurora, Ill.

IN THE year 1912 the writer was named superintendent of the new water purification plant in the city of Grand Rapids, Mich. The Grand Rapids plant proved a distinct challenge in public relations problems as well as a stimulating adventure in operating procedures that lasted for over seventeen years. Out of those experiences evolved a whole philosophy of ways to deal with the public that still today prove highly satisfactory.

At least one-third of Grand Rapids' population were of Holland descent. They were as fine a group of citizens as ever crossed the ocean, but traits of inherent conservatism strongly inclined them to be skeptical of the new-fangled plant that was going to put chemicals into their drinking water. In fact, the whole citizen body of Grand Rapids were in doubt. Pleasing as was the sudden change from the raw, turbid, hard and discolored water formerly pumped from the Grand River to the soft, sparkling and potable effluent from the new filtration plant, it was necessary to enter into a direct selling campaign to combat prejudice and doubt.

There were constant and repeated questions raised by telephone, at meetings, on the street corners and at the city hall. "Why does lime make water hard and how does lime make water soft?" "Does not lime coat the stomach as in the teakettle?" "If lime is used to decompose dead bodies, is it alright to use it in our drinking water?" "If we use the water to scrub our porches, will it take the paint off?" "I am going to wash my hair; will this new water turn it red?" "We want to water the lawns; will this water kill the grass?" "Why does it take more of this new water to quench our thirst?" These questions and many more were asked for a long time. The questions had to be answered, and answered satisfactorily.

The superintendent was faced not only with the duty of operating the plant but also with the problem of so winning the trust and confidence of the water user that the city officials and other public-spirited men responsible for its being financed and built would be fully justified. Of the two problems, that of winning the public's confidence was the more important and the more difficult.

Planned Talks Help

The situation was met by planning talks illustrated by chemical experiments showing how the plant did its work. The process was discussed in easily understandable terms, punctuated with experiments that made clear the use of alum and lime and in such a way as to generally answer all their questions. These talks proved so popular that for almost three years after the starting of the plant there was scarcely a month without two or three speaking dates. Care was taken to state facts, allay fear and solicit confidence. The type of talk was varied to suit the group. Every sort of audience was talked to, ranging from parent-teachers' groups to dinner clubs and ladies' aid societies. Even the sermon hour in a large downtown church was occupied one Sunday evening.

At the plant visitors were welcomed but were not allowed to aimlessly wander about. They were carefully piloted around the plant and shown how it did its work with appropriate explanations. In the meantime there was gradually built up a whole gallery of display bottles, charts, diagrams and records designed to be simple, informative and helpful. Every effort was made to impress upon the visitor the fact that the plant belonged to him.

The visitor had a right to be there and to ask questions and be instructed in the plant's workings. The plant was continuously visited by individuals and groups and especially on Saturday afternoons and Sundays. Thus there rapidly developed a friendliness for and understanding of its work that gradually dispelled the feelings of doubt which were raised at first. The people met in groups, gathered for instruction, created a wide and friendly acquaintanceship with the plant's personnel that was of the greatest service during the many periods when the plant was not producing a perfect effluent.

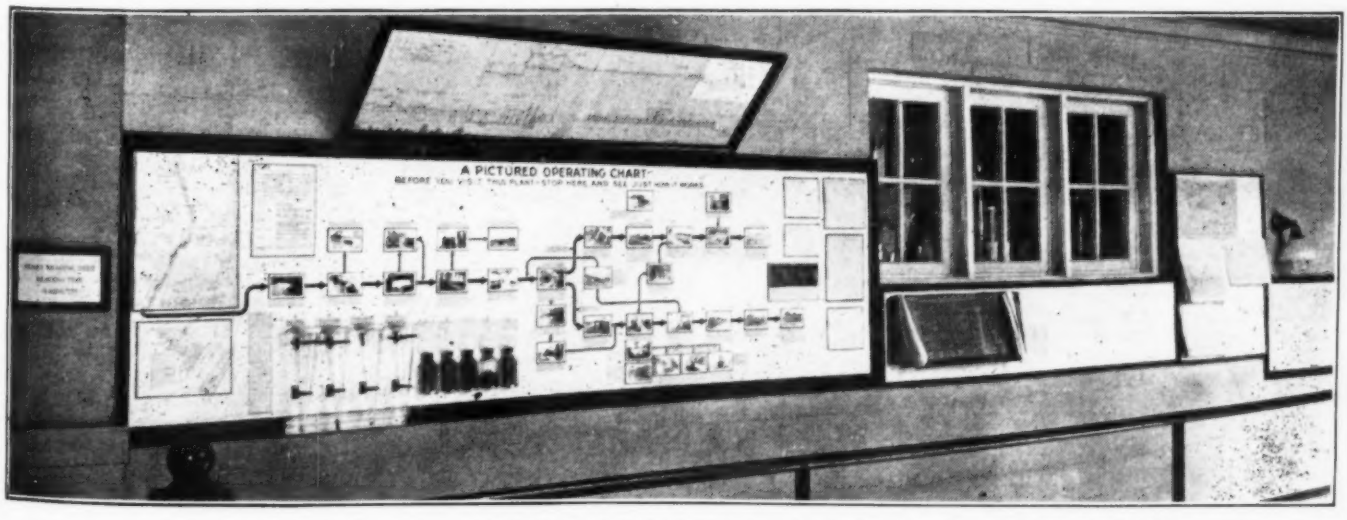
One of the most valuable experiences with the public's sufferance with plant operating mistakes occurred soon after the plant was started, and is worth relating. The lesson learned in that experience paid good dividends for many years.

One day a strong chlorine taste developed that did not appear generally until near evening. On returning from the theater we received reports of numerous phone calls concerning it, but there had been no chlorine taste at home before going to the theater nor was any noticed after returning. At the plant the next morning a thorough search of the records for the preceding day was made but no clue as to the source of the taste was found. In the meantime the director of public service had come out to discuss the problem. It so happened that the director was peculiarly chary about any adverse publicity. Shortly after his return to the city hall one of the plant employees revealed the cause of the preceding day's taste.

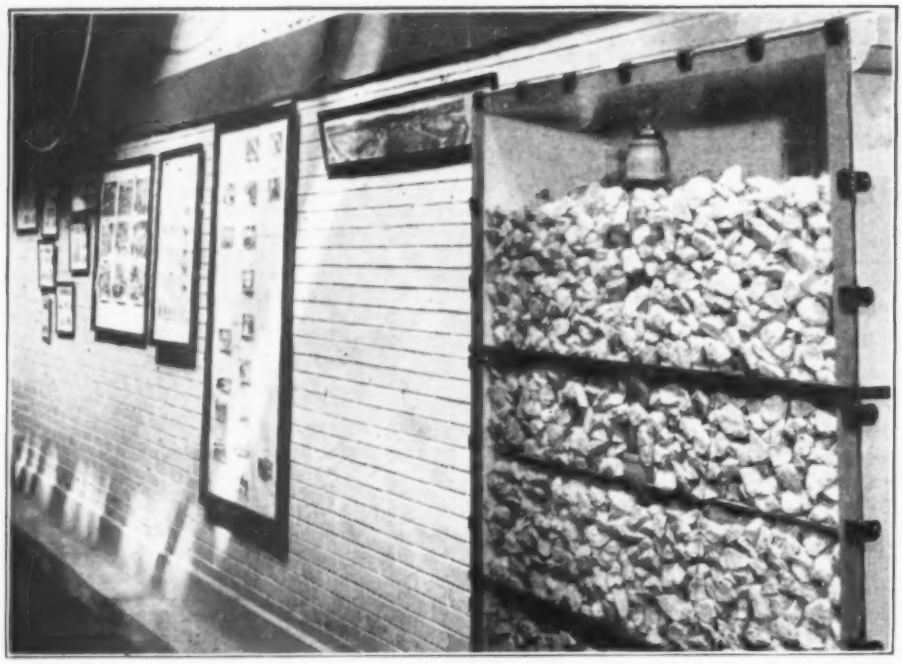
Tell the True Story

A large accumulation of lime dust had been removed from the limestorage tower and "saved" by throwing it into the incoming raw water. What escaped attention, at the time, was the fact that there was also stored in the same tower hogsheads of chlorinated lime. The chlorine gas distilling from these hogsheads had been absorbed by the lime, partially converting it to chlorinated lime. The discharge of this material into the raw water resulted in a heavy momentary overdose of chlorine that passed through the plant and water mains in an ever widening circle and so disappeared. Clearly it was an unfortunate accident. At the moment of this discovery the evening paper called for information. Contrary to any advice that surely would have been given by the lately departed service director, the full and complete story of the accident was given to the press. The story came out that evening with all details correctly stated.

It is certain that this early demonstration of the policy of a full and complete explanation of the reason for undesirable blemishes in the quality of water being delivered was highly beneficial. Such a public confession given to the newspapers was based on the fact that the plant belonged to the whole citizen body, who had the right to know the truth about their drinking-water supply. Moreover, the plant was a complicated machine, and it was not humanly possible to operate perfectly every single day of the year.



General Plant Flow Chart with Hydraulic Section Above—Records and Charts Are at the Right



Typical Display of Model, Charts and Pictures at Aurora Plant

Occasionally, try as one might, accidents would happen. All reasonable persons would recognize this fact. If news releases failed to recognize this fact, denied the presence of trouble or failed to give reasonable explanations, the public would quickly sense deception and lose confidence in the plant and its personnel. Therefore, by adopting the policy of careful and truthful explanations of faults, confidence and trust were built up. Time and again citizens calling to ask "why trouble" would usually leave the telephone with an apology for disturbing us, confident that the trouble would soon be in hand. The incident is related fully because it is a valuable lesson in public relations based upon a sound philosophy, the operation of which was tested to the writer's satisfaction for many years.

While this paper is being written primarily for the benefit of the sewage plant operater, it is clear that the problems of both water and sewage treatment plants are the same. The lessons learned through twenty years of water purification plant operation are equally applicable to sewage plants. The sewage plant superintendent should clearly understand and accept the fact that his work as superintendent includes an obligation to interest and inform the citizens of his community. Plant superintendents, therefore, should plan devices for the benefit of visitors that obviously indicate their welcome and right to visit.

Ability to Speak, Important

One of the prime requisites of a superintendent is too often neglected. It ranks almost equally with technical skill, and it is the ability to speak and write good English. It takes time and mental effort to reduce a technical description of a process to a short, easily understandable statement that will convey meaning to a layman. This kind of skill is required to properly set up a visitors' leaflet or to phrase the explanatory signs and notes which may be posted about a plant for visitor guidance.

There is always a thrill connected with the ability to explain the mysteries of a plant's operation to a visitor. The writer well remembers the little old lady from Iowa who mostly raised chickens and who was being shown through the plant one day. Half way through she beamed on him with sparkling eyes, exclaiming, "Why, I am really understanding it!" No better illustration could be given as to the truth of the theme of this paragraph.

The capacity to speak acceptably before dinner clubs and at public gatherings is almost without price. If the topic assigned has been presented in clear, simple, logical, thought-provoking language, there will be marked attention—always a compliment. There will also be an implied pride in the possession by the group of a plant so represented. Furthermore, there will be an undue assignment of skill to the speaker—very possibly undeserved—because this is the way clear, forceful speaking affects an audience. Because, through the years these principles have been demonstrated, the ability to write and speak is re-emphasized.

Fill Bare Spots on Walls

Bare spaces on the walls of a plant have always been a challenge to fill them with a variety of instruction charts and diagrams. The planning of instruction exhibits can easily become a pleasant and profitable hobby. All they require is a good idea combined with a modest ability to draw and a knack for developing an idea for quick and easy understanding. When neatly framed or mounted they accumulate gradually into an attractive gallery for public instruction. Do not be discouraged, however, if they are not always studied too carefully by John Citizen. They still perform a useful purpose. They make bare walls attractive. They indicate a personnel interested in the work of the plant and therefore persons who likely are faithful public stewards. Whether the visitor cares to take the trouble to understand them or not, they are mute evidence that his interests are being cared for. Finally they are a challenge to the operator himself to maintain a high standard.

To illustrate the variety of exhibits that can be planned to make the visiting of a plant interesting, the following list of displays at Aurora are given:

Framed Ground Plan showing plant layout. Scale 1 inch equal 25 feet. Dimensions 3 by 3½ feet.

Complete Flow Diagram with pictures of all apparatus accompanied by explanatory notes. Framed board 2¾ by 10 feet.

Picturized vertical section of all structures showing hydraulic gradient through the plant. Framed dimension 1½x5 feet.

Pin map of sewage plants in Illinois.

Pin map of all cities over 1,000 population having sewage treatment in the United States framed 2 by 3¼ feet.

Map of the Fox River with pictures and notes of the twenty-three plants located on the river.

Glass fronted model of the sprinkling filters showing a full scale section.

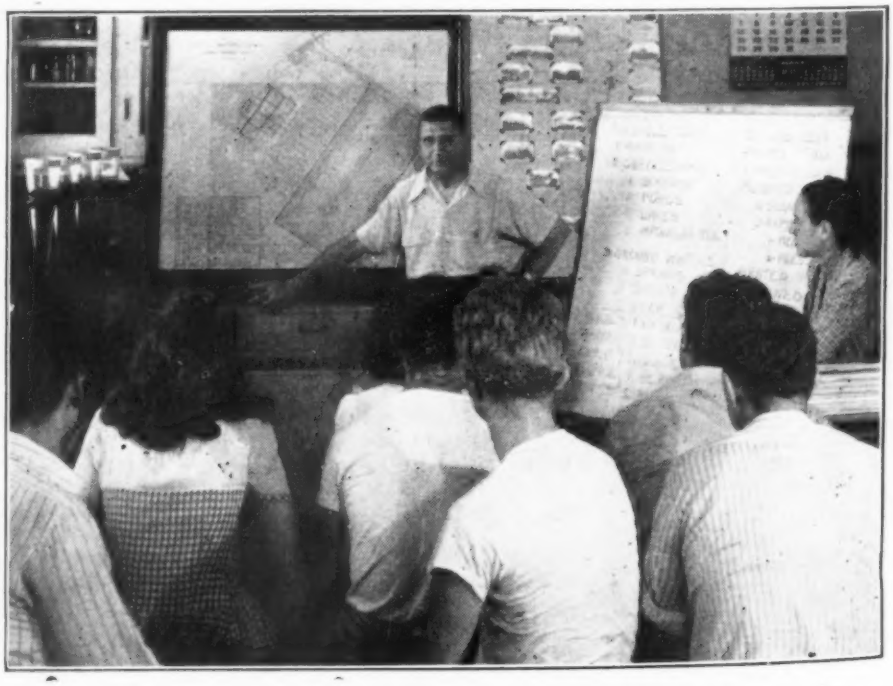
Accumulating file of the regular monthly data sheets showing all chemical and physical data and posted monthly.

17 framed groups of pictures of plants elsewhere.

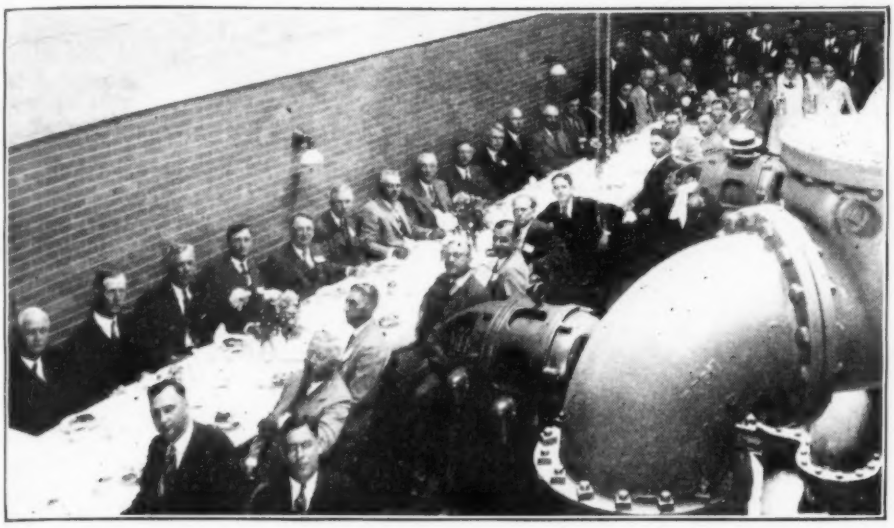
Current year curves, added to monthly, showing:

A. Gas production and distribution.

B. Suspended solids and 5-day B.O.D. data with per cent removal curves.



Aurora College Class in Bacteriology Sitting Through a Typical Class Session



Dinner Meeting in the Aurora Sewage Plant

C. Oxygen content of Fox River, cfs flow in river and pounds of oxygen demand by raw and effluent sewage with curve of per cent oxygen demand removed by treatment.

Curves showing typical hourly flow of sewage to the plant for each day of the week together with the hourly load of suspended solids and 5-day B.O.D. load carried.

A series of framed statements placed at appropriate places about the plant to explain that portion. These enable the visitor to follow the process step by step. For details of wording see *Sewage Works Jour.*, page 380, July, 1931.

The general mechanics of plant arrangements to receive visitors is completed by providing a descriptive leaflet. While the collection of such material in the writer's files takes many forms as to size, style and type of printing, cost and general elaborateness, a simple four-page leaflet, half letter size, is preferred. A good form of leaflet should have an attractive plant picture, a well-planned flow diagram and plant layout, a simple, well-worded description of the plant, the process employed and a few well-chosen statistics. Such a leaflet printed on good paper can be made attractive enough to tempt reading and is quite inexpensive. It makes a pleasing souvenir to terminate an instructive visit. They are particularly useful to complete sessions with school classes.

Conducting Classes Through the Plant

One of the pleasant "must" duties of a superintendent is that of receiving and conducting classes about the plant. For the most part such classes will come from the chemistry departments of the local high schools. Grade schools, however, may send classes, and hospitals will send students in nursing. Groups from other sources may bring the total annual number of such groups up to ten or fifteen. Since the individuals of all such groups are potentially the men and women, and therefore the taxpayers of tomorrow, there should be a definite program of procedure to meet their needs. They should be handled so as to favorably impress them with the need and value of this particular unit of the municipal machine. The visit should never be allowed to get out of hand and degenerate into a lark.

The plan adopted at Aurora works well. Classes are received by appointment. They are received, therefore, when it is convenient and with the stage set. Since the period allowed from school is short, the program (which never varies) must be closely timed. Plank benches have been set up in the laboratory to accommodate thirty students. Imhoff cones with raw, clarified, filtered and effluent sewage are on display. The large plant layout plan is in place, together with the pin map of plants in the U. S. and the map of the Fox River showing pictures of the plants along its banks. Depending on the nature of the class, a series of instruction charts on an easel for quick reference are set up. Thus the class is immediately seated on arrival in a previously prepared place with no chance to scatter. After a half hour of intensive discussion, with a short period for questions, the class is conducted through the plant, being careful to follow the sewage flow as previously discussed. Thus the whole procedure is kept on such a high level of serious discussion and interest that disciplining is unnecessary. No class has ever failed to respond to the plan. Nurses' classes, having more time, are given a much longer lecture, since their visit to the plant may be their only opportunity of receiving some brief instruction in the field of sanitary engineering as related to water, sewage and garbage problems. Aurora has now completed plans for building extension and remodeling. *These plans include the unique feature of a special room fitted up to receive and instruct classes.*

An invitation to be the speaker of the day at one of the local dinner clubs is a happy combination of compliment and opportunity. Fortunate is the superintendent who has cultivated a small capacity to meet such a speaking date acceptably. Most clubs contain a good cross section of the business and professional men of the community. These men are quick to appraise a good program. Your date, well filled, thereby becomes a real asset in good-will and appreciation. It is certain that if the first club talk is good that invitations will soon come to appear before other clubs. Furthermore, plant superintendents should belong to a local dinner club. It is a sure way to cultivate friendliness and an understanding of his contribution to the community welfare.

Club Meetings at Plant with Meals

As a corollary to a club speaking date an arrangement to have a club meeting at the plant is excellent. Aurora has had several such meetings. They were much enjoyed. Usually some church women's group is glad to prepare the meal. Cooked in the laboratory and nicely served at a sewage plant, it is a long-remembered novelty. The plan may be varied according to the season of the year and the space available. It may take the form of a lawn party with box lunches or a picnic. Either event is a good scheme.

With this is included an account of public relations experiences that have proved successful for the past thirty years. The very first requisite for success as a superintendent of a sewage plant is that he should be sold on his job, in the Presbyterian sense of being "foreordained and predestined" to it. The writer feels that most of them are.

A good superintendent will possess at least four personal characteristics: Intelligence—he must be well informed. Friendliness—he must like people and be easy to approach. Patience—to deal with folks that have "gripes." (Most "gripes" result from misinformation. Such people are dealt with by patiently letting them fully expend their spleen, after which they can be reasoned with.) Plain honesty—the superintendent's public must have the sure feeling that their plant is in competent hands.

The physical background for good public relations include:

(a) Inviting plant approaches.

(b) Well-kept and attractive grounds with lawns, trees, shrubs and flower beds.

(c) A clean plant. Good housekeeping automatically implies good operation in the eyes of the visitor.

(d) A well-defined visitors' program. It should include:

1. Some ability to speak and write.
2. A well-designed visitors' leaflet.
3. The walls of the plant decorated with helpful and interesting charts, diagrams and pictures.
4. The plant should be posted with short descriptive paragraphs in sufficient number and so placed that a visitor can readily read his way through.
5. A well-planned program of procedure for classes.
6. A supply of bottles for samples, a spotlight and interpretive charts and diagrams for use in making acceptable talks before outside groups.
7. If occasionally a dinner club or other group can plan a dinner with an inspection tour of the plant afterwards, it helps.

THE CLARK CONTROLLER CO.

MANUFACTURERS OF ELECTRICAL CONTROL APPARATUS

1146 East 152nd St. **Cleveland 10, Ohio**

Represented in

Akron, Ohio
Birmingham, Ala.
Boston, Mass.
Buffalo, N. Y.
Charlotte, N. C.
Chicago, Ill.
Cincinnati, Ohio
Cleveland, Ohio
Dallas, Texas
Denver, Colo.
Detroit, Mich.
Gary, Indiana
Houston, Texas
Huntington, W. Va.
Kansas City, Mo.
Los Angeles, Cal.
Minneapolis, Minn.
New York, New York
Omaha, Neb.
Philadelphia, Pa.
Pittsburgh, Pa.
Portland, Oregon
St. Louis, Mo.
Salt Lake City, Utah
San Francisco, Cal.
Tampa, Florida
Tulsa, Oklahoma
Youngstown, Ohio

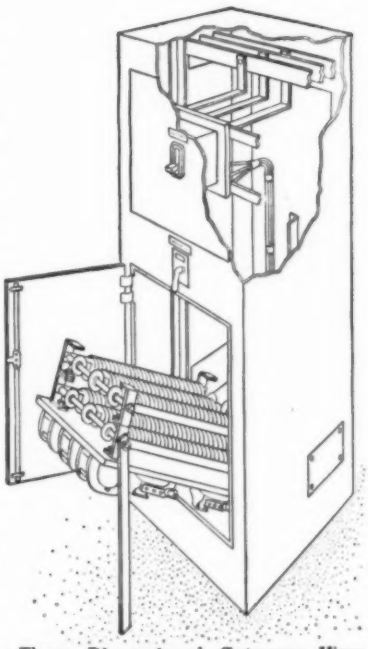
For many years The Clark Controller Company has supplied Electrical Control Apparatus for motor driven machinery in sewage disposal, water treatment, and other Public Works installations.

By analyzing hundreds of such installations, Clark engineers found that three basic panel forms —Incoming Line, Motor Control, and Gauge Cubicle—were used in practically all of them.

Standardization of these forms resulted in Clark Bulletin 9900 Cubicle Control Centers—each section matching the others in overall height, depth, general construction, and appearance. Variations are wholly dependent upon the total number and size of the motors with which the control is used.

The cutaway drawing illustrates the sturdy switchgear type of construction used, arrangement for continuous bus, swingout construction for reduced voltage starting panels, and other details for simplified front of board maintenance.

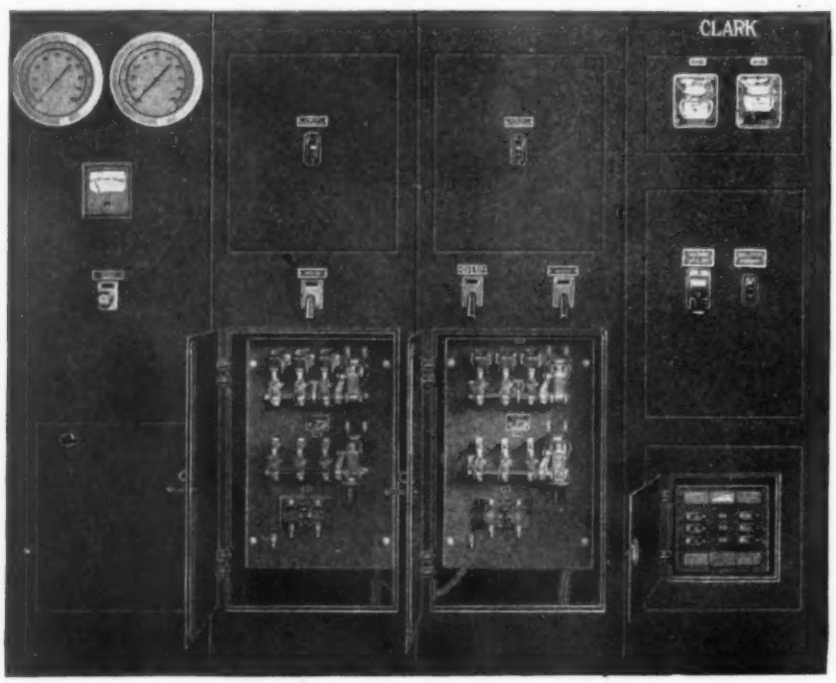
It is easy for Architect, Engineer, Contractor or ultimate purchaser to determine the Cubicle equipment needed for a given installation. Clark Descriptive Bulletin 9900 gives simple, easily understood tables from which the size and type of Cubicle can readily be selected. Physical arrangement of Clark Cubicle Control Centers can be made to suit the installation. Neat, compact, matching dead front Cubicles can be added to the original installation at any time should expansion of facilities become necessary.



Three Dimensional Cutaway View of a Motor Control Cubicle.

Clark Bulletin 3600 Float Switches, Bulletin 4900-50 Pressure Switches, and Bulletin 100 Push Buttons provide sturdy, reliable actuating devices, and remote control where desired.

Ask for fully descriptive Bulletins 9900, 3600, 4900-50 and 100. Any Clark District Office or Agency will be glad to give you full details.



Typical Installation with Type G Gauge Cubicle, two Type M1-R3 Motor Cubicles and Incoming Line Cubicle Type 1L-225.

CENTRIFUGAL PUMPS*

Some Notes on Selection of the Proper Pump and A Simple Method of Checking Pump Efficiencies

By H. E. BECKWITH, Engineer
The Pitometer Company
New York, N. Y.

SOME twenty years ago when I first entered the water works field steam driven displacement type pumps were in general use. But, today we find the great majority of pumping stations equipped with electrically driven centrifugal pumps, with an occasional Diesel driven or turbine driven centrifugal installation. The old slow moving reciprocating pump of yesterday could always be depended upon to take care of changing pumping loads and varying heads without any great loss in efficiency. But, this is decidedly not so with the modern centrifugal pump, designed to work under rather fixed conditions. Any appreciable variation from these conditions is accompanied by a falling off in efficiency, which may be rather marked.

Unfortunately, the non-technical water works operator who got his early practical experience with the old displacement type of pump has not always become sufficiently acquainted with the characteristics of the centrifugal pump. Only too often the only demand made on a centrifugal pump is that it pump water, and little or no attention is paid to the efficiency with which it does its work. In fact the average water works man is usually not acquainted with any simple method of determining this efficiency.

It is, therefore, the purpose of this article to point out the conditions which may be expected to cause low operating efficiency, and to outline a simple method for testing the wire-to-water efficiency which gives results as close as is necessary in practical water works operation.

Basic Principles of the Centrifugal

As a youngster I used to tie a chestnut on the end of a string and whirl it around my head until I had imparted to it the force necessary to take it flying through the air at high speed. You did it, too. The principle of building up velocity of that chestnut by whirling it about the head is the same principle which is used in the design of a centrifugal pump. The water which enters the pump through the suction inlet is seized by the rotating vanes of the impeller and spun until it is rotating at terrific velocity. Since pressure and not velocity is desired, the pump is so designed that by gradually slowing down this velocity in the casing of the pump, the energy stored up in this rapidly moving water is almost entirely changed to pressure. The speed of the chestnut rests upon two factors—the length of the string and the number of revolutions made within a specified period of time. The speed, and hence the resulting pressure, imparted to water by a centrifugal pump also rests upon the same two factors—the diameter of the impeller and the number of revolutions per minute which the impeller makes.

There are, of course, practical limits to both the speed and the diameter so that it is not always possible to secure the full desired pressure with one pump. If not, the water is passed through two or more pumps in series, and each pump raises the pressure part of the total desired amount. Sometimes these two or more pumps are built in one pump case, in which instance each pump is called a "stage" Since electrically driven centrifugal pumps operate at fixed speeds, there is always one head under which a pump will operate most efficiently. Right here it will not hurt to repeat that any material deviation from this condition will result in decreased efficiency.

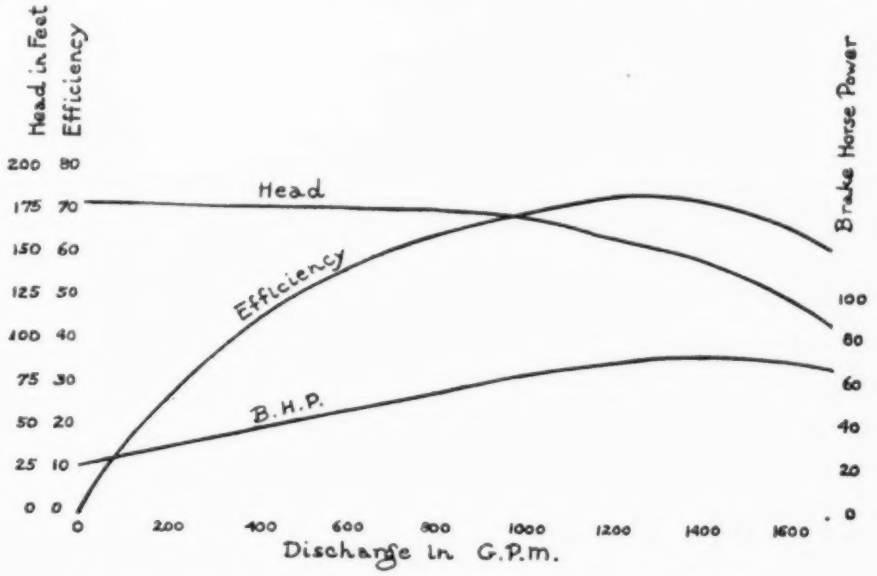
Pump Performance Curves

At this point I want to introduce a typical centrifugal pump curve which we will use for illustration during this discussion. Similar curves are available from the manufacturer for all medium sized and large pumps. On small pumps it is not customary to furnish such performance curves.

It will be noted from an inspection of the specimen curve that the greatest efficiency for this particular pump (about 75%) is secured when the head is about 155 ft. and the discharge rate is about 1,300 G.P.M. You will also note that as the head is materially increased or decreased from the optimum head there is a large change in the pumping rate and a considerable drop in efficiency. A great deal has been done in design effort to widen out the "peak" of the efficiency curve into a "plateau" so as to give high efficiencies for centrifugal pumps under a wider range of operating conditions. Considerable progress has been made in this direction.

Friction Head—Its Importance

Let us see what happens when we forget to include pipe friction loss when figuring the total head against which the pump must operate. If we have figured on the pump whose curve we have, and if we are pumping through two miles of 16" main, the friction loss will add about 18 ft. to the pumping head—making it 173 ft. At this head (see curves) the pumping rate will drop to 1,000 G.P.M. and the efficiency to 70%. Furthermore, the pump is operating on a very critical part of the curve where a slight increase in pumping head—caused by tuberculation in the main or by any other reason—would incur a precipitate drop in both the efficiency and the pumping rate. It also illustrates what can happen to a pump, after installation, when the pumping head has been increased above the head for which it was designed. As



An Example of Typical Performance Curves for Centrifugal Pumps. Various designs show individual characteristics in respect to the curves produced.

* Excerpts from a paper presented before the Penna. Water Operators Association and an earlier article by Mr. Beckwith in previous Reference & Data Issues of this magazine

it is the nature of unlined iron and steel mains to tuberculate, resulting in a constantly rising friction loss, this is an important consideration.

Let us illustrate this in another way.

Selecting the Right Pump

Suppose that we are in the market for a 1,000 G.P.M. pump operating against a total head of 173 ft., and a pump whose curve we have been using has been submitted for consideration. I would not consider this pump a good "buy" to operate under these conditions. In the first place it will be noted that the efficiency of 70% is much below the maximum efficiency of 75%. But even more important, perhaps, is the fact that the pump at 173 ft. head is operating under "critical head" conditions. An increase of only about 8 ft. (less than 5%) in the pumping head would bring the head to the maximum which the pump can create—in other words to the "cut off" point. This means that an increase in the head of only 8 ft. (about 3½ pounds) would decrease the pumping rate from 1,000 G.P.M. to zero G.P.M. Moreover an increase of only 3 ft. in head would cause a drop of 200 G.P.M. in the pumping rate. On the other hand, when we are working in the most efficient range of the pump a change of 3 ft. in the head would only cause a variation of 30 to 40 G.P.M. in the pumping rate; and, the efficiency is practically unaffected.

It follows, therefore, that one should buy a pump within the range where the efficiency curve is as *flat* as possible and the head curve is as *steep* as possible. In this connection a word of warning may not be amiss. By making the vertical scale of the curve less than is customary, a much flatter *appearing* efficiency curve can be secured. So in comparing the performance curves of pumps be sure that they are plotted on comparable scales. I have known curves with reduced vertical scales to be submitted where I felt sure that the scale was deliberately reduced for the purpose of deception.

Mistaken Economy

Only too often in the revamping of a plant, efforts are made to re-use as much of the old equipment as possible. It may be assumed that if the old pump will handle 1,300 G.P.M. against 155 ft. of head it should have less trouble pumping the same amount from the river to the settling basin against a head of only forty or fifty feet. This is so. In fact, if we will look at the curve we will find it will pump much more than 1,300 G.P.M. at the lower head. The curve does not go out that far, but it goes far enough to show what would happen—not only to the pumping rate but to the efficiency as well. The pumping *rate goes up* but the *efficiency goes down*—yes, way down. Reducing the head has a tendency to cause a pump to run away much as an automobile would run away down hill when the going becomes easier if the throttle were not closed to compensate for the decreased demand for power. This running away of the pump sometimes overloads the motor so that it runs hot. To prevent this, operators raise the head artificially by partly closing a valve on the outlet side of the pump. This decreases the load on the motor and brings the pumping rate back to normal. But it burns up a great deal of power needlessly as the closed valve destroys part of the head generated by the pump and only part of the work actually performed is effective. I have known of installations, such as this, where the installation of a new pump saved more than enough power in one year to pay the entire cost of the new pump and motor and also completely depreciate the old unit replaced.

But it is not always necessary to buy a new pump just because the head has been reduced. If we will get back to that chestnut on the string we will find that we can reduce the speed of the chestnut by reducing the length of the string, at the same time keeping the number of revolutions constant. In the same manner, we can cut down the pressure generated by a constant speed centrifugal pump by reducing the diameter of the runner. If the reduction in head is moderate, the manufacturer can advise you how much will have to be machined off the outside of the present impeller so that it will pump efficiently, or at a slight expense he will furnish a new impeller for the changed conditions. Or he may cut down your old impeller.

It is sometimes possible to secure a larger impeller to efficiently handle increased heads, but in this case the motor is likely to be overloaded unless the original specification anticipated such change as loads increased.

Another way to increase the speed of that chestnut would be to keep the length of the string constant and to increase the number of revolutions. It follows that if we increase the revolutions of any centrifugal pump we will increase the head which that pump will generate. This explains why a certain pump tested last fall gave a wire to water efficiency of only 40%. This pump was designed for use with a gasoline motor and to operate under the then existing head conditions at a speed of 1400 R.P.M. Eventually electric power became available and the pump was connected to an electric motor and the speed increased to 1,800 R.P.M. This, of course, increased the head generated by the pump itself, and the efficiency was consequently very low.

A somewhat similar condition was found several years ago when a 5 M.G.D. installation designed to work against a head of 100 pounds was found to have been connected in series to a 5 M.G.D. pump designed to pump against 50 pounds pressure. This gave an installation with a design head of 150 pounds, but the actual head was still only about 100 pounds. The *output* was thereby *increased* to approximately 6 M.G.D. but the *efficiency decreased* to the point where it was only slightly above 40%. New and properly designed equipment brought the wire-to-water efficiency up to about 75%.

It can be readily seen from the above considerations that the chances of buying a suitable pump from the "junk man" are just about nil. It might be "as good as new" for the conditions for which it was designed and yet be absolutely worthless under any other conditions. In fact, it would probably be a most expensive liability. Yet pumps have been bought from the equivalent of "junk men", but most frequently have been "salvaged" by the original purchaser for other duty than originally purchased for.

So far, we have been discussing equipment which has been working under conditions which made it impossible to give a creditable showing. A mere inspection of the conditions and a knowledge of the design limitations would make it evident that satisfactory performance under these conditions could not be secured. However, there are occasions where, after installation, things happen to properly selected pumps which will cut the efficiency of the equipment. There was, for instance, the time

Table I—Gallons of Water Delivered per Kilowatt Hour Against Various Heads on Theoretical Assumption That Pump and Motor Are 100 Per Cent Efficient

H = head in feet. G = gallons per kilowatt hour

H	G	H	G	H	G	H	G	H	G	H	G	H	G	H	G	H	G	H	G
1	118,200	51	6,240	101	3,151	151	2,108	201	1,583	251	1,268	301	1,058	351	907	401	794	451	706
2	159,100	52	6,120	102	3,120	152	2,094	202	1,575	252	1,263	302	1,054	352	904	402	792	452	704
3	106,100	53	6,005	103	3,090	153	2,080	203	1,567	253	1,258	303	1,051	353	902	403	790	453	703
4	79,560	54	5,894	104	3,060	154	2,067	204	1,560	254	1,253	304	1,047	354	899	404	788	454	701
5	63,650	55	5,786	105	3,031	155	2,053	205	1,552	255	1,248	305	1,044	355	897	405	786	455	700
6	53,040	56	5,683	106	3,002	156	2,040	206	1,545	256	1,243	306	1,040	356	894	406	784	456	698
7	45,460	57	5,583	107	2,974	157	2,027	207	1,537	257	1,239	307	1,037	357	892	407	782	457	697
8	39,780	58	5,487	108	2,947	158	2,014	208	1,530	258	1,234	308	1,033	358	889	408	780	458	695
9	35,360	59	5,394	109	2,920	159	2,002	209	1,523	259	1,229	309	1,030	359	887	409	778	459	694
10	31,830	60	5,304	110	2,893	160	1,989	210	1,516	260	1,224	310	1,027	360	884	410	776	460	692
11	28,930	61	5,217	111	2,867	161	1,977	211	1,508	261	1,220	311	1,024	361	882	411	775	461	691
12	26,520	62	5,133	112	2,842	162	1,965	212	1,501	262	1,215	312	1,020	362	879	412	773	462	689
13	24,480	63	5,051	113	2,816	163	1,952	213	1,494	263	1,211	313	1,017	363	877	413	771	463	687
14	22,730	64	4,972	114	2,794	164	1,940	214	1,487	264	1,206	314	1,014	364	875	414	769	464	686
15	21,220	65	4,896	115	2,766	165	1,929	215	1,480	265	1,202	315	1,011	365	873	415	767	465	685
16	19,890	66	4,822	116	2,741	166	1,917	216	1,474	266	1,197	316	1,007	366	870	416	765	466	683
17	18,720	67	4,750	117	2,720	167	1,906	217	1,467	267	1,193	317	1,004	367	868	417	763	467	682
18	17,680	68	4,680	118	2,697	168	1,894	218	1,460	268	1,188	318	1,001	368	865	418	761	468	680
19	16,750	69	4,611	119	2,674	169	1,883	219	1,453	269	1,184	319	998	369	863	419	760	469	679
20	15,910	70	4,547	120	2,652	170	1,872	220	1,447	270	1,179	320	995	370	860	420	758	470	677
21	15,150	71	4,482	121	2,630	171	1,861	221	1,440	271	1,175	321	992	371	858	421	756	471	676
22	14,470	72	4,420	122	2,609	172	1,851	222	1,434	272	1,170	322	989	372	856	422	754	472	675
23	13,830	73	4,360	123	2,588	173	1,840	223	1,427	273	1,168	323	986	373	854	423	753	473	674
24	13,260	74	4,301	124	2,567	174	1,829	224	1,421	274	1,162	324	982	374	851	424	751	474	672
25	12,730	75	4,243	125	2,546	175	1,819	225	1,414	275	1,158	325	979	375	849	425	749	475	671
26	12,240	76	4,188	126	2,526	176	1,809	226	1,408	276	1,154	326	976	376	847	426	747	476	669
27	11,790	77	4,133	127	2,506	177	1,798	227	1,402	277	1,150	327	973	377	845	427	746	477	668
28	11,370	78	4,080	128	2,486	178	1,788	228	1,396	278	1,146	328	970	378	842	428	744	478	666
29	10,970	79	4,028	129	2,467	179	1,778	229	1,390	279	1,142	329	968	379	840	429	742	479	665
30	10,610	80	3,978	130	2,448	180	1,768	230	1,384	280	1,137	330	965	380	838	430	740	480	663
31	10,270	81	3,929	131	2,429	181	1,758	231	1,378	281	1,133	331	962	381	836	431	739	481	662
32	9,945	82	3,882	132	2,411	182	1,749	232	1,372	282	1,129	332	959	382	833	432	737	482	660
33	9,644	83	3,834	133	2,393	183	1,735	233	1,366	283	1,125	333	956	383	831	433	736	483	659
34	9,360	84	3,789	134	2,375	184	1,729	234	1,360	284	1,121	334	953	384	829	434	734	484	658
35	9,093	85	3,744	135	2,358	185	1,720	235	1,354	285	1,117	335	950	385	827	435	732	485	657
36	8,840	86	3,701	136	2,340	186	1,711	236	1,349	286	1,113	336	947	386	825	436	730	486	655
37	8,601	87	3,658	137	2,323	187	1,702	237	1,343	287	1,109	337	945	387	823	437	729	487	654
38	8,375	88	3,617	138	2,306	188	1,693	238	1,337	288	1,105	338	942	388	820	438	727	488	652
39	8,160	89	3,576	139	2,292	189	1,684	239	1,332	289	1,102	339	939	389	818	439	725	489	651
40	7,956	90	3,536	140	2,274	190	1,675	240	1,326	290	1,098	340	936	390	816	440	723	490	650
41	7,762	91	3,497	141	2,257	191	1,666	241	1,320	291	1,094	341	934	391	814	441	722	491	649
42	7,577	92	3,458	142	2,241	192	1,658	242	1,315	292	1,090	342	931	392	812	442	720	492	647
43	7,401	93	3,422	143	2,225	193	1,649	243	1,310	293	1,087	343	929	393	810	443	719	493	646
44	7,233	94	3,386	144	2,210	194	1,640	244	1,304	294	1,083	344	926	394	807	444	717	494	644
45	7,072	95	3,350	145	2,195	195	1,632	245	1,299	295	1,079	345	923	395	805	445	716	495	643
46	6,916	96	3,315	146	2,180	196	1,624	246	1,294	296	1,075	346	920	396	804	446	714	496	642
47	6,771	97	3,281	147	2,165	197	1,615	247	1,288	297	1,072	347	918	397	802	447	712	497	641
48	6,630	98	3,248	148	2,150	198	1,608	248	1,284	298	1,068	348	915	398	800	448	710	498	639
49	6,493	99	3,215	149	2,136	199	1,600	249	1,278	299	1,065	349	913	399	798	449	709	499	638
50	6,365	100	3,183	150	2,122	200	1,592	250	1,272	300	1,061	350	910	400	796	450	707	500	636

when we found a water snake wrapped around the shaft with the result that the inlet ports were partially cut off and the suction lift increased way beyond the 15 feet maximum for best performance. In another and similar situation blocks of wood were found jammed in the ports. Then there was the time that low efficiency was caused by the blowing of the gasket of a multiple stage pump and the water was short circuiting back from a higher stage to a lower stage. One of our engineers once reported that an efficiency of 20% was caused by the impeller slipping on the shaft.

Two interesting conditions have been found by the author which have no reference to the actual efficiency of the pumps but which were determined as the result of making efficiency tests. In one instance, where the meter through which power was purchased was used to measure the power input, it was found that an apparent low efficiency was caused by this meter being set 20% high. In another instance, a pump was discharging into a closed distribution system. On the basis of the water *actually discharged* into the system (24-hour period) the pump had an efficiency of only 8%. Had a standpipe or reservoir been floating on this system, the same amount of water could have been pumped with about one-eighth the amount of power which was actually used.

So much for the reasons why efficiency tests should be made at intervals.

A Simple Efficiency Test

The writer has worked out a simple method for making efficiency tests which he has been using with satisfactory results for some years.

At one foot of head and 100% efficiency of *both pump and motor* it is theoretically possible to raise 318,200 gallons of water one foot with one KW.H. To determine this theoretical value for any other head, simply divide 318,200 by the head involved. For instance, the value at 159 ft. would be $\frac{318{,}200}{159} = 2{,}001.2$ gallons per KW.H. In this connection the accompanying "Table of Theoretical Values for Various Heads" may prove helpful in reducing calculations in pump testing. It was prepared by the writer and has appeared in earlier Reference and Data Numbers of WATER WORKS AND SEWERAGE.

To determine the *wire-to-water efficiency* of an installation it is only necessary to divide the actual pumpage per KWH by the theoretical value for the pumping head, as determined from the table. A rough check can be made by dividing the month's pumpage in gallons by the KWH consumed. This gives the gallons actually pumped per KWH.

Test Procedure

With the pump running, determine the total head in feet (including suction) against which the pump works. Divide 318,200 gallons by this total head (as above) to determine the theoretical 100% pumpage per KWH. (Or take the figure from Table 1.) Next divide the actual gallons per KWH by the theoretical gallons per KWH to secure the wire to water efficiency.

To illustrate:

Assume a monthly pumpage of 32,640,000 gallons and a monthly power consumption of 30,200 KWH. Say the total head noted was 220 ft. Dividing 32,640.000 by 30,200 gives an actual pumpage of 1,081 gallons per KWH. Dividing 318,200 by 220 ft. gives a theoretical value of a possible 1,447 gallons per KWH at 100% efficiency (see table). Then;

$$\frac{1{,}081 \text{ (observed)}}{1447 \text{ (theoretical)}} = 74.7\% \text{ overall}$$

wire to water efficiency.

A more accurate method of making the tests is to measure the power input for an hour, or some other convenient period of time. During this period carefully check the output of the pump with any suitable main line meter. Keep a close record also of the discharge pressure and of the suction. The integrations on most electric meters in pumping stations cannot be read closely enough for short tests. However, the power company will furnish the number of watts consumed for each revolution of the disk, and by counting its revolutions for ten or twenty minutes the rate of power input can be closely ascertained. Or the power company can be asked to measure the power by means of special equipment. Where more than one pump is taking power through the master meter at the same time, the latter method is the only feasible one for testing each unit separately.

Securing Total Head

The total head in feet must first be secured. If the pressure gauge reads in pounds, convert to feet by multiplying the pounds of pressure by 2.31 [feet of water head giving one pound gauge pressure]. The suction will probably be expressed in inches of mercury. Convert this to feet of water head by multiplying by 1.13. Also measure the vertical distance between the center of the pressure gauge and the point of suction measurement. The total head then becomes the sum of the following:

Discharge pressure, in feet	xxx
Suction, in feet	xx
Vertical distance pressure gauge is above point of suction measurement, feet	x
Total Head in feet	xxx

Velocity head has been ignored, as it is a small factor for the relatively high heads which usually exist in water works operation.

If water is delivered to the pump under pressure, then the pump will be working against a head equal to the difference between the discharge pressure and the inlet pressure.

From the data secured during the test, determine the gallons delivered per kilowatt hour. As before, divide this by the theoretical value for the head against which the pump was operating. This gives the overall wire-to-water efficiency of the installation.

As an example, let us assume an installation where we secured the following test data:

Power input to motor	90.0 K.W.	
Rate of discharge	51,840 gals. per hr.	
Delivery per KWH	576 gals.	
Pressure	146 lbs. =	337 ft.
Suction	15 ins. =	17 ft.
Difference in gauge elevation	1 ft. =	1 ft.
Total head		355 ft.

Theoretical discharge at 335 ft. head (see table) is $\left(\frac{318{,}200}{355}\right) = 897$ gals.

and

Overall efficiency (wire-to-water) is $\left(\frac{576}{897}\right) = 64\%$

If a suction gauge is not available, an approximation may be secured by measuring the vertical distance from the level of water in the clear well to the center of the pressure gauge, adding to this measured distance about two feet for loss in bends, etc.

What the Tests Reveal

Having shown the desirability of frequent tests and having presented a simple method for making them, it may now be interesting to discuss what these tests may be expected to show. In the first place, there have been great increases in the attainable efficiencies of centrifugal pumps within the past few years. Those of modern design may be expected to give up to the following overall (wire to water) efficiencies.

Capacity G.P.M.	Efficiencies Percent
200	58
400	63
600	68
800	71
1000	73
1500	75
3000	80
5000	82
Over 5000	85

It will be noted that the larger the pump the higher the efficiencies.

There will be variations from these figures depending upon the head and other conditions. Such are submitted only for the purpose of giving something with which to compare the efficiencies of existing installations. This is important, because it will often be found that older equipment may have retained its original efficiency and yet be so inefficient in comparison with modern equipment, now available, that it is decidedly not economical to keep it in operation. It will be worth while to check the present efficiency of every centrifugal pump now more than ten years old, to determine how great a reduction in power consumption can be secured by replacement with more efficient modern pumps. You may be surprised.

If an old 1,000 gpm pump, operating at an efficiency of 57% is replaced with a new pump giving an overall efficiency of 73%

the same amount of water may be pumped with 22% less power. This means that both the demand rate and the power consumption through each step of the existing rate schedule would be decreased 22%. Such a reduction might prove enough to pay for the new installation in about one year's time. In order to get the gallons per KWH to be expected at any head, for any efficiency, it is only necessary ot determine theoretical gallons per KWH for that head and then to multiply this theoretical value by the expected efficiency. If the total pumpage in gallons is then divided by this expected pumpage per KWH the power consumption to be anticipated from the new installation will be secured. Similarly it is possible to determine the anticipated demand rate, which is often as important as is the total KWH consumption in determining the power bill to be expected from a new installation. Sometimes it is more important.

A Worthy Example

In the March, 1939, issue of WATER WORKS AND SEWERAGE an article by Messrs. Marshall and Rawlins of Charlotte, N. C., revealed graphically how the power costs were drastically cut at the local pumping station by replacing old equipment with new. These power costs, which had been running about $16.00 per million gallons were cut to about $7.50 per million gallons. This cut was the result of two definite and distinct improvements. In the first place the pumping main was paralleled with a new line. This resulted in reducing the former friction loss materially. This single betterment cut the power cost from $16.00 to $12.00 per million. Following this, the not very old (but less efficient) pumping units were replaced with modern efficient equipment. This investment, which might appear to the average municipal councilman a questionable expenditure, further reduced the pumping cost to $7.50 per million, representing a very notable day in and day out saving.

Measuring Output of Water

Table I has another use. Many plants, especially smaller ones, have no master meters. With the old displacement type pump it was possible to secure the approximate amount of water pumped by installing a pump stroke counter and multiplying the number of strokes by the discharge in gallons per stroke. If the pump were permitted to get into a state of disrepair, this measurement was apt to be in error, but if the pump were kept in good condition it was reasonably accurate. The method about to be outlined for obtaining the output of water from electrically operated centrifugal pumps has possibly a degree of accuracy comparable to the pump counter method.

From the efficiency curve furnished with the pump, determine the pump efficiency for the head under which the pump operates. The curve will show the pump efficiency only. The combined pump and motor efficiency, the so-called wire to water efficiency, will be about 90 per cent of the efficiency shown for the pump alone. From Table I secure the theoretical gallons per kilowatt hour for the head under which the pump is operated. Multiply this by the overall wire to water efficiency just secured. This gives the number of gallons per kilowatt hour the pump should deliver. Multiply this by the total number of kilowatt hours used over any given period of time and the result should be the number of gallons pumped over the same period. To illustrate:

Assume a pump with an efficiency of 65 per cent operating at a total head of 200 ft. Then 90 per cent of 65 would give an overall wire to water efficiency of 58.5 per cent. If the installation were 100 per cent efficient, Table I indicates the discharge would be 1,592 gallons per kilowatt hour. With an overall efficiency of 58.5 per cent the discharge would be 1,592 × 58.5 per cent, or 931 gal. If the power consumption for the month be 20,000 kilowatt hours, then the total pumpage becomes 20,000 × 931 or 18,620,000 gal. for the month.

While this method of computing pumpage will not, as a rule, give results as satisfactory as those secured from a master meter, it does give a close approximation in instances where a master meter is not available.

In outlining the tests in this paper it has not been intended to supplant the more detailed methods used by professional engineers, but to make available to the average water works operator a method of checking which will give reasonably accurate results.

TERMINOLOGY IN PUMPING*

Static Head

Static Head is the vertical distance in feet between the free level of the source of supply and the point of free discharge, or to the level of the free surface of the discharge water.

Total Dynamic Head

Total Dynamic Head, as determined on test, where Suction Lift exists, is the reading of a mercury column connected to the suction nozzle of pump, plus the reading of a pressure gauge connected to discharge nozzle of pump, plus vertical distance between point of attachment of mercury column and center of gauge, plus excess, if any, of Velocity Head of discharge over Velocity Head of suction as measured at points where the instruments are attached, plus head of water resting on mercury column, if any.

Total Dynamic Head, as determined on test, where Suction Head exists, is the reading of a gauge attached to the discharge nozzle of pump, minus the reading of gauge connected to the suction nozzle of pump, plus or minus vertical distance between centers of gauges (depending on whether suction gauge is below or above discharge gauge), plus excess, if any, of Velocity Head of discharge over Velocity Head of suction as measured at points where instruments are attached.

Total Dynamic Discharge Head, is the Total Dynamic Head minus Dynamic Suction Lift, or plus Dynamic Suction Head.

Total Dynamic Head is the vertical distance between source of supply and point of discharge when pumping the required capacity, plus Velocity Head, plus friction and entrance losses.

Suction Lift

Suction Lift exists where the source of supply is below the center of pump.

Static Suction Lift is the vertical distance from the free level of source of supply to center of pump.

Dynamic Suction Lift is the vertical distance from the source of supply, when pumping required capacity, to center of pump, plus Velocity Head, plus entrance, and friction losses; but not including internal pump losses.

Dynamic Suction Lift, as determined on test, is the reading of a mercury column connected to suction nozzle of pump, plus vertical distance between point of attachment of mercury column to center of pump, plus head of water resting on mercury column, if any.

Suction Head

Suction Head (sometimes called Head on Suction), exists when source of supply is above center of pump.

Static Suction Head is the vertical distance from the free level of the source of supply to center of pump.

Dynamic Suction Head is the vertical distance from the source of supply, when pumping at required capacity, to center of pump, minus Velocity Head, minus entrance, and friction losses; but not minus internal pump losses.

Dynamic Suction Head, as determined on test, is the reading of a gauge connected to suction nozzle of pump, minus vertical distance from center of gauge to center of line pump. Suction Head, after deducting the various losses, may be a negative quantity, in which case a condition equivalent to Suction Lift will prevail.

*From "Hydraulic Data," an Ingersoll-Rand Hand-Book.

R-S Products Corporation

Valve Division, Wayne Junction, Philadelphia 44, Pa.

R-S Butterfly Valves for Control and Shut-off

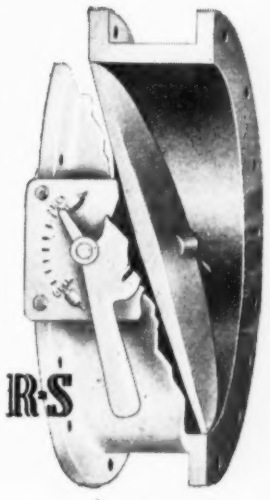
Distributors in the following cities:

(Telephone Listing is "R-S Products Corporation, Valves")

Atlanta
Appleton, Wis.
Baltimore
Boston
Buffalo
Charlotte, N. C.
Chicago
Cincinnati
Cleveland
Corpus Christi
Denver
Des Moines
Detroit
Houston
Indianapolis
Los Angeles
Milwaukee
Minneapolis
New York
Philadelphia
Pittsburgh
Richmond, Va.
Rochester, N. Y.
San Francisco
Seattle
St. Louis
Tulsa
Washington, D. C.
Monterrey, N. L., Mexico
Panama, Pan.
Caracas, Venezuela

SIMPLICITY, light weight, small space requirement, and low cost identify R-S Butterfly Valves. They give shut-off control and perfect regulation of the volume and pressure of everything that moves through pipes. The precisely machined beveled disc makes a wedge-type closure against the body of the valve. Abrasive materials "fan out" rather than "jet" as the valve approaches full closure. In open positions the disc creates a Venturi action, recovering pressure on the down-stream side. The streamlined disc and straight body-bores make R-S Butterfly Valves self-cleaning. There are no angles nor pockets nor changes of Flow-direction to trap impediments in the valve or create turbulence in the stream. R-S Butterfly Valves are fully closed and fully opened quickly. Control of flow or pressure is uniform over 99% of the adjusting range.

Butterfly Valves are indisputably the best for many purposes. Engineering research has made R-S the best of Butterfly Valves.



USES

Shut-off and regulation of volume and pressure
Pressure relief
Control of
- liquid level
- back pressure
- water hammer
- steam hammer
- constant differential pressure
- output of pumps, fans, engines, turbines
- automatic-combustion

For:
- Air
- Gas
- Liquids
- Steam
- Semi-Solids

TEMPERATURE RANGE

—300° F. to plus 2000° F.

THREADS

U. S. Standard
American Sanitary

SIZES

1" to 84"

FLANGES

Spiral Pipe Mfrs.
American Standard
A. G. A.
U. S. Navy

PRESSURES

2 to 2500 psi

TYPES OF CONTROL

Hand lever
Chain lever
Hand wheel
Chain wheel
Electric motor
Solenoid trip
Air Diaphragm motor
Float
Hydraulic Cylinder
Air Cylinder
Automatic controls can be furnished with positioner if desired

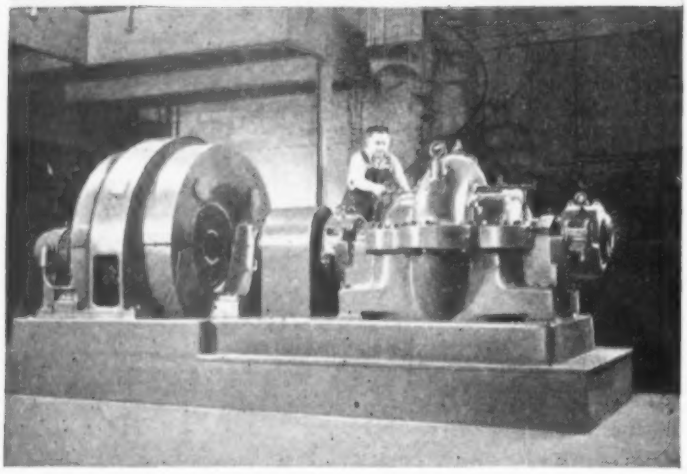
TYPES OF METAL

Aluminum
Brass
Bronze
Cast Iron
Meehanite
Cast Steel
Monel Metal
R-S "A" Metal (anti-abrasive)
R-S "H" Metal (heat-resisting)
Stainless Steel or any material that can be cast or welded

Full descriptions and specifications in R-S Catalog 14-B. Send for your copy. Address R-S Products Corporation, Valve Division, Wayne Junction, Philadelphia 44, Pa.

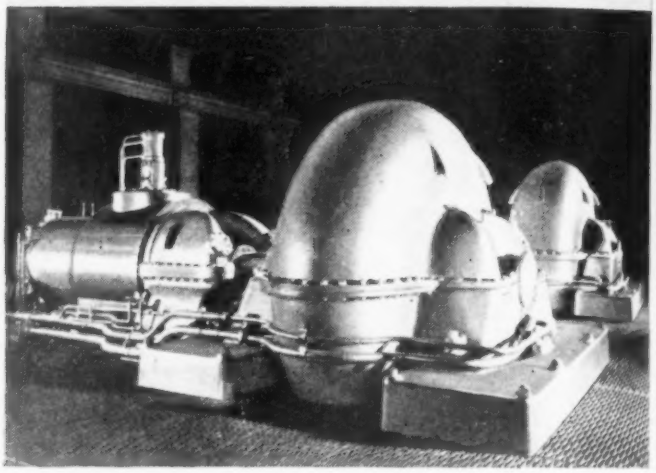
World's Widest

CENTRIFUGAL PUMPS



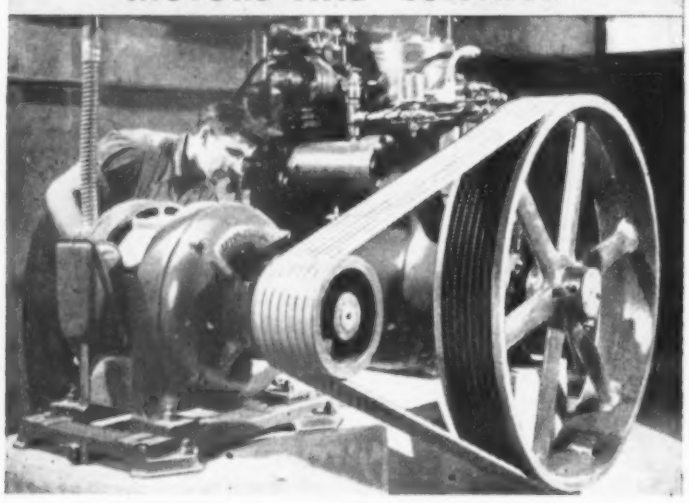
MIDWEST PUMPING station uses Allis-Chalmers pump-motor "team." A-C builds *all types of pumps for water and sewage works, fire protection, drainage and other public works.* Capacities range up to the largest. A-C can also supply any type and size of motor or steam turbine drive.

BLOWERS AND COMPRESSORS



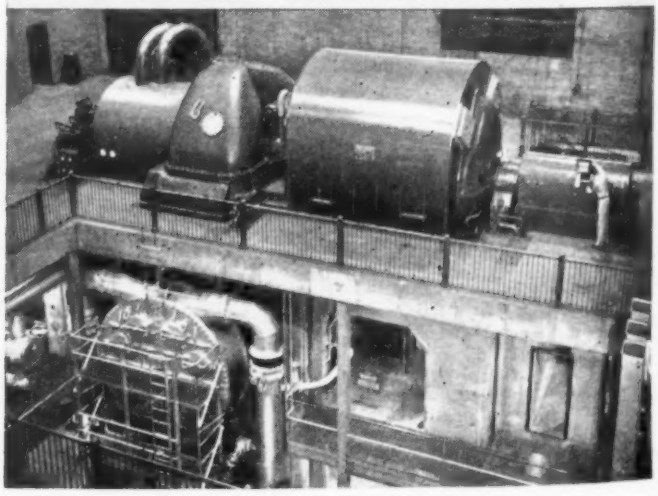
ALLIS-CHALMERS turbine-driven centrifugal blowers in Milwaukee sewage treatment plant. A-C builds multi-stage blowers up to 130,000 cfm, 35 psig; single-stage—600 to 35,000 cfm, 1 to 6.25 psig; rotary compressors—44.5 to 1,684 cfm, 5 to 35 psig; vacuum pumps—14.5 to 5,300 cfm, 18 to 28.5 in. hg.

MOTORS AND CONTROL



GENERAL OR SPECIAL purpose motors from *1 hp to 7,000 hp and over* are built by Allis-Chalmers. Motor control is also available to fulfill any requirement. And famous Texrope V-belt drives fit applications of power transmission from *fractional to 6,000 hp,* constant or variable speed.

TURBINES AND CONDENSERS



POWER PLANT INSTALLATION in Lansing, Michigan equipped with Allis-Chalmers turbine and condenser. For over 40 years A-C has been providing power stations with *all types and sizes* of steam turbines and condensers. Auxiliaries include air ejectors, circulating water, condensate, and boiler feed pumps.

Send for NEW Public Works Bulletin

Description of A-C equipment — published for Public Works engineers. Send for your copy today. Bulletin 25B6607, ALLIS-CHALMERS, MILWAUKEE 1, WIS.

Range OF MAJOR PUBLIC WORKS EQUIPMENT!

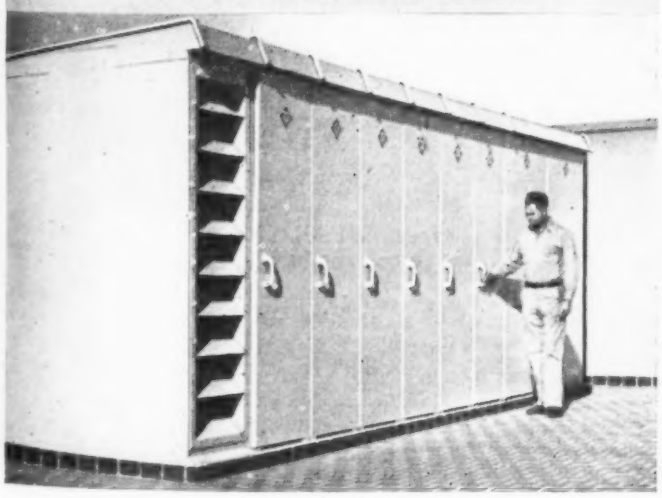
At Allis-Chalmers You Get Complete Line Ranging from Power Generation to Processing Machinery

WHAT DOES THIS LEADERSHIP in range of public works equipment mean to you? It means that you can get individual units of equipment *tailor-made to work together* . . . designed and built by one company.

Engineers know that for maximum efficiency, equipment must work as a team—*the right drive for the right pump—the right control with the right motors.* It is this coordination of equipment that saves you money and engineering worries. No other company offers you this kind of equipment engineering. No other company can supply you with so many different types of major equipment with emphasis on making them work together as an efficient team.

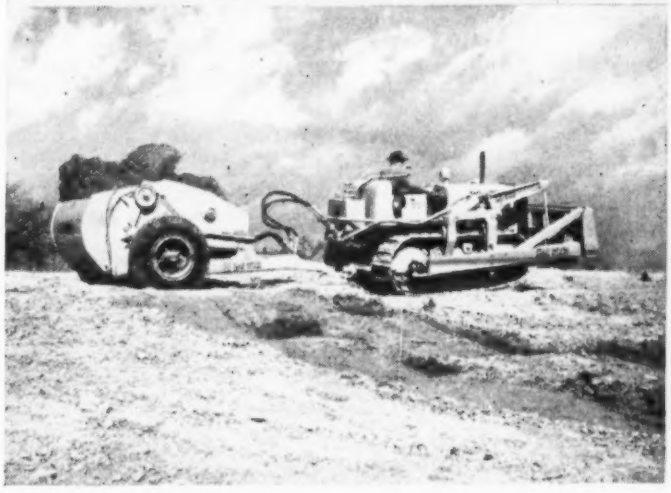
Whether you are planning to modernize or expand, call on Allis-Chalmers. Get in touch with your nearest A-C office or write to ALLIS-CHALMERS, MILWAUKEE 1, WIS.

POWER DISTRIBUTION



PROTECTING MOTORS in West Coast pumping station—that's the important job of this Allis-Chalmers metal-clad switchgear. Completing the Allis-Chalmers power distribution line are transformers, circuit breakers, unit substations, motor generator sets, mercury-arc rectifiers, switchboards and industrial control.

HIGHWAYS AND PROCESSING



WHEEL AND TRACK-TYPE tractors, power units and motor graders are available in the *wide A-C line* of highway equipment. Auxiliaries are tampers, shovels, scrapers, rippers, bulldozers, mowers, sweepers, cranes and snow plows. Processing equipment; vibrating screens, crushers, kilns, sifters, and roller mills. A 2234

ALLIS·CHALMERS

One of the Big 3 in Electric Power Equipment — Biggest of All in Range of Industrial Products

1847 1947
A CENTURY OF SERVICE
to Industry
THAT MADE
America Great

ROSS VALVE MFG. CO., INC.

TROY, NEW YORK

AUTOMATIC CONTROL & PRESSURE REGULATING VALVES

***For* Water Works and Fire Departments**

For accurate service, the automatic control and pressure regulating valves must be right as to type and size for the service required. Our W. R. Type, cast iron, bronze mounted valves in sizes from 4" to 30" are guaranteed for services for which they are designed.

Altitude Valves

Single Acting

Model 40 AWR — semi-throttling hydraulic control to prevent overflow of tank, standpipe or reservoir or to maintain a positive adjustable head for washing and filtering operations. Pilot adjustment range—4 to 30 ft., 30 to 60 ft., 60 to 150 ft.

Model 30 AWR—wide open or closed hydraulic control to prevent overflow of tank, standpipe or reservoir. Pilot adjustment range 4 to 30 ft., 30 to 60 ft., 60 to 150 ft.

Other single acting altitude valves combine back pressure or relief valve and pressure reducing functions.

Double Acting

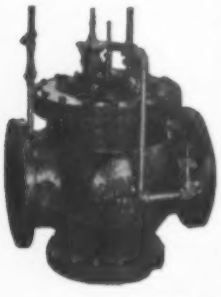
Model 40 DAWR—to prevent overflow in tank or reservoir and to allow return flow to distribution system when head on tank side is three inches higher than head of distribution system. These valves may be equipped with Remote Hydraulic and Electric Control. When required the return flow can be delayed for a predetermined pressure drop in distribution. Pilot adjustment range—4 to 30 ft., 30 to 60 ft., 60 to 150 ft.

Other double acting altitude valves combine many additional features to prevent dumping of tank, to retain supply on off peak loads and to make available maximum storage for peak load periods. Also a semi-throttling model for gradual closing of feed line and for maintenance of adjusted pressure on the distribution side. Can be equipped with secondary pilot to close valve if break occurs in distribution system.

Surge — Relief — Back-pressure Valves

Model 50 RWR—Single Pilot, Electric and Hydraulic Control—for protection against excessive pressures in distribution systems, supply lines and pump discharge lines. Intaliled in discharge line of deep well pump, provides constant back pressure to prevent overdrafting of the well. Pressure range in pilot—10 to 60 lbs., 20 to 150 lbs., 125 to 250 lbs.

Float Valve or Level Controller



Model 50 FWR—External Pilot Operated—to control main valve so that main stem operates wide open or closed. Pilot valve wastes to atmosphere contents only of operating chamber each time valve stem rises to open position. Maximum inlet pressure, 175 lbs.

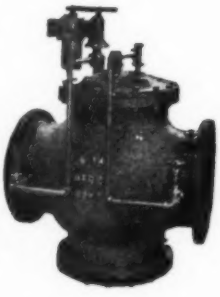
Model 40 FWR—External Pilot Operated, Semi-throttling—for gradual closing of valve during last three inches before overflow.

Reducing and Regulating Valves

Model 40 WR—Single Pilot, Hydraulic Control—to maintain constant desired discharge pressure regardless of rate of flow or pressure on upstream side of valve. As a pressure reducing valve, operates to:

1. Control and regulate pressures in gravity and pumping systems.
2. Regulate flow between reservoirs and zones of different pressures.
3. Regulate fire flows between zones of unequal pressures.
4. Regulate pressures in filter wash lines and aerator nozzles.

Valves operate without waste of water to atmosphere and will not induce surge. Can be equipped with dual pilot to permit changing from one pressure to another by mere operation of a three-way cock for systems operating under different day and night pressures. Valves may be supplied with right-angle body. Pressure range outlet—10 to 60 lbs., 20 to 150 lbs., 125 to 250 lbs.



Model 40 WR—Single Pilot, Electric Remote Control—motor driven, geared to pilot adjusting tail screw, made with limit stops to prevent over-travel, and operated by push button switch.

Pressure Reducing and Reverse Flow Valves

Model 50 WR—Single Pilot, Hydraulic Control—for installation at dividing line between two zones to reduce pressure from higher zone, to function as a sleeping valve, discharging into low zone at a time of excessive draft, to permit flow from low to high zone when excessive draft in high zone reduces its pressure below that of the low zone as in case of fire. Pressure range outlet—15 to 60 lbs., 20 to 150 lbs. This valve may be equipped with dual pilot control to permit greater ranges in pilot control and to provide the assurance which goes with duplication and stand-by units.

FIRE DEPARTMENT SPECIALTIES

Portable Fire Hydrant Head for Pressure Reduction—Internal Pilot Operated—for attachment to high pressure main; carried on apparatus to fire, one man can attach (110 lbs. weight) in 18 to 30 seconds, four 2½" hose connections delivering independently from shutoff to full pressure and a fifth connection 2½" to 3" delivering full pressure.

Hose Valves for Pressure Reduction
Fire Engine Relief Valves

All Ross Valves Repaired in Line: Internal Packing Replaced Through Top of Valves.

WATER HAMMER

Its Study and Correction

By HENRY RYON

Late Senior Sanitary Engineer
New York State Department of Public Works, Albany, N. Y.

IN ORDER to provide water for Clinton Prison at Dannemora, N. Y., it was found necessary to use Chazy Lake as a source of supply and to lift the water over Dannemora mountain to the prison reservoir. This required the installation of a pumping station and a force main about 4½ miles long with a rise of 530 feet. The pumping station and pipe line were put in operation late in 1932, and almost immediately trouble was experienced due to the failure of the lead joints in the pressure line. The cause of these failures was apparently the high pressures developed when the pumps were stopped, and studies were made to determine the best method of reducing these high pressures.

Installation

The pumping equipment consists of two electrically driven four-stage centrifugal pumps each having a capacity of 390 gallons per minute against a head of 619 feet. The pumps are set approximately at normal lake level. The suction line is of 10-inch cast iron pipe and is about 400 feet long. The discharge main is of 8-inch cast iron bell and spigot pipe, Class G to Class B, and is 23,720 feet long. The static head at the pumps is 530 feet, the equivalent of approximately 230 pounds per square inch. There is a standard swing check valve on the suction line and a similar check on the discharge line of each pump. A 6-inch spring loaded relief valve and an air chamber 8 inches by 96 inches in size were provided on the main discharge line near the pumps.

Line Pressure

In order to study the pressures in the discharge line a recording pressure gauge with a fast moving chart was connected to the line just beyond the relief valve. A typical pressure curve plotted by this gauge with one pump in operation and the relief valve and air chamber shut off is shown in Fig. 1.

The static pressure is 230 pounds per square inch. When one pump is started the pressure gradually rises to 310 pounds per square inch, the rise for each of the four steps of the starter showing distinctly, and then drops to the running pressure of 275 pounds per square inch. When the pump is stopped the pressure drops very quickly from 275 pounds per square inch to 90 pounds per square inch and then rises to 370 pounds per square inch. These subnormal and supernormal pressures continue at regular intervals, the variations above and below the static pressure becoming less and less as line friction gradually damps them out. The time of one complete cycle is 23.1 seconds, and since the water-hammer wave must travel four times the length of the pipe in one cycle, its velocity is at the high speed of 4,110 feet per second. By comparison, the maximum velocity of flow in the pipe, with one pump in operation, is only 2.49 feet per second.

It is, of course, the first super-normal pressure wave that causes most of the damage to the pipe line. The subnormal pressure wave cannot, however, be neglected for it very definitely limits the amount of air that can be retained in the air chamber.

Water Hammer Waves

In order to explain the method evolved to control the water-hammer pressures, it is necessary to consider first the nature of a water-hammer wave. The magnitude and velocity of the wave depend upon the elasticity of the material composing the pipe wall, the velocity of the water in the pipe and the time in which that velocity or part of that velocity is extinguished. The yare independent of pressure in the pipe and flow velocity, except that part of the velocity that is extinguished. The water-hammer pressure or excess pressure is the variation above or below normal caused by the water-hammer wave. In this case (and in other cases where conditions are similar) the momentum ceases to deliver water almost instantly. The suction line being short, no high pressure of any duration is developed in it that of the rotating parts of the pump and motor is so small in comparison with the load that when the switch is opened the pump might force water through the pump. As a result the stopping of the pump has for all practical purposes the same effect as almost instantaneously closing a valve.

An Analysis

This effect can be examined best by considering the pipe line to be divided into a large number of very small sections of equal length.

When a valve at the inlet end of a pipe in which water is flowing is instantaneously closed, the velocity of the water in the section adjacent to the valve (in this case the pump), is immediately extinguished. This causes the water in this first section to expand, the pressure to fall and the pipe to contract. In other words, the kinetic energy of the moving water has been converted into potential energy. The water in the first section being at rest or static, the velocity of the water in the second section must necessarily cease. The water in the second section then expands, the pressure falls and the pipe contracts in the same manner as in the first section. This reduction in pressure in the second section in no way affects the pressure in the first section for the pressure in that section, excepting gravity and friction, is dependent entirely upon the destruction of the kinetic energy of the water in that section. And, the kinetic energy of the water

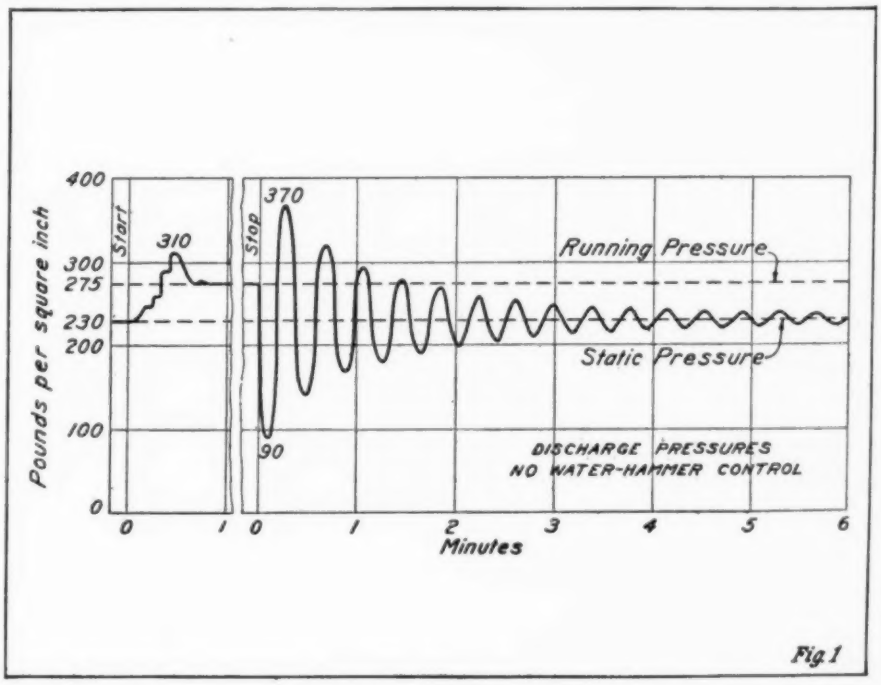


Fig. 1.—Typical Pressure Wave Graph
(One Pump Thrown Out; Relief Valve and Air Chamber Shut Off At the Time)

in the second section is exactly the same as that of the water in the first section and its destruction therefore produces exactly the same reduction of pressure. This process continues through the third, fourth and other sections of the pipe until all the water in the line has expanded, the entire pipe line contracted and the pressure throughout fallen by the same amount. The wave has traveled the length of the pipe once and the water is at rest.

This condition, however, is not stable. The water in the lower end of the pipe cannot move, but the water in the upper end is freeto contract. This it does immediately. The water in the upper section contracts, the pressure rises and the pipe expands. As a result of this contraction of the water and the expansion of the pipe in the upper section, water flows into the pipe. Conditions in the upper section having thus changed, the second or adjacent section is free to move. The water in the second section then contracts, the pressure rises and the pipe expands. This draws more water into the pipe. In a like manner similar changes occur in the third, fourth and other sections until all the water in the line has again contracted, the entire pipe line expanded and the pressure throughout risen to the point (excepting friction at which it was before the valve was closed or the pump stopped. The wave has traveled the length of the pipe twice. The water is in motion and is flowing toward the pump with the same velocity, excepting for friction losses, at which it was flowing away from the pump before the pump was stopped.

This flow cannot continue, for while the wave has been traveling twice the length of the pipe, ample time has elapsed (11.5 seconds in this case) for the check valve at the pump to close tightly. The flow is therefore directed toward a closed valve and the velocity in the first section adjacent tothe check valve is instantly extinguished. The water in this section is compressed, the pressure rises and the pipe expands. The water in the first section being at rest, the water in the second section must necessarily come to rest with the same changes in condition as occurred in the first section. In a like manner, the water in the third, fourth and other sections come to rest successively until all the water in the pipe line is at rest and compressed, the pressure above normal and the pipe expanded for its entire length. The wave has traveled three times the length of the pipe and the water is once more at rest.

Again, however, the conditions are unstable. The water in the lower end of the pipe cannot move but that in the upper end is free to expand. This it does immediately. The water in the first section expands, the pressure falls and the pipe contracts causing water to flow out of the upper end. Conditions having changed in the upper or first section, the second section is free to move. The water in the second section then expands, the pressure falls and the pipe contracts causing a further flow of water out of the upper end of the pipe. Similar changes occur in the third, fourth and other sections of the pipe until all the water in the pipe has expanded, the entire pipe line contracted and the pressure (except for friction losses) fallen to the normal running pressure. The wave has traveled the length of the pipe four times. The water is moving away from the pump with the same velocity, excepting friction losses, that it was before the pump was stopped. In other words, one cycle has been completed, and conditions are the same as when the pump was running.

The cycle repeats itself until the friction gradually damps out the wave.

A diagram of the effect of this wave near the pump is shown in Fig. 2. The complete cycle is from A to G. The slope of the line from B to C is due to the fall in friction pressure as the wave passes up the pipe and the water gradually comes to rest.

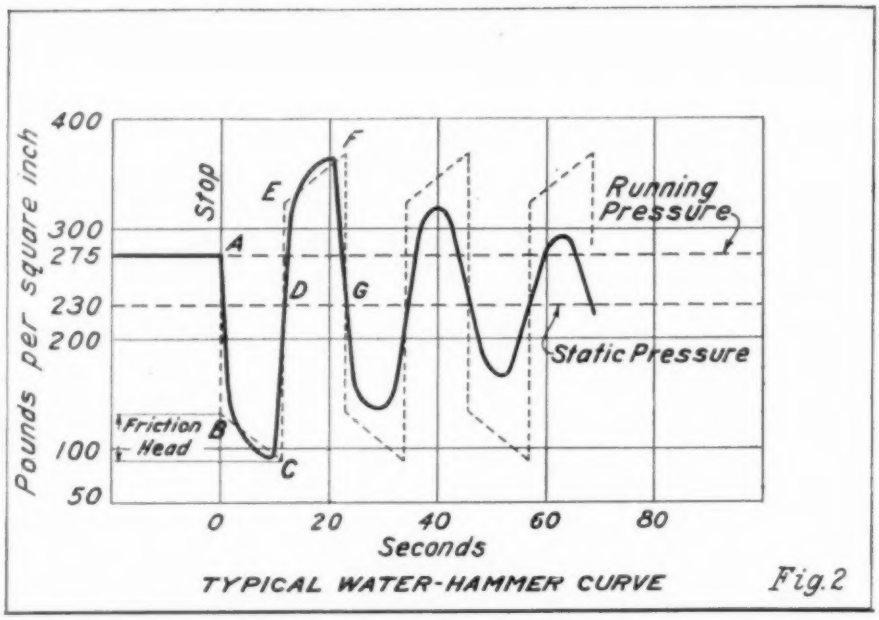


Fig. 2.—Graph of Wave Near the Pump (Explanation of Significance in Text)

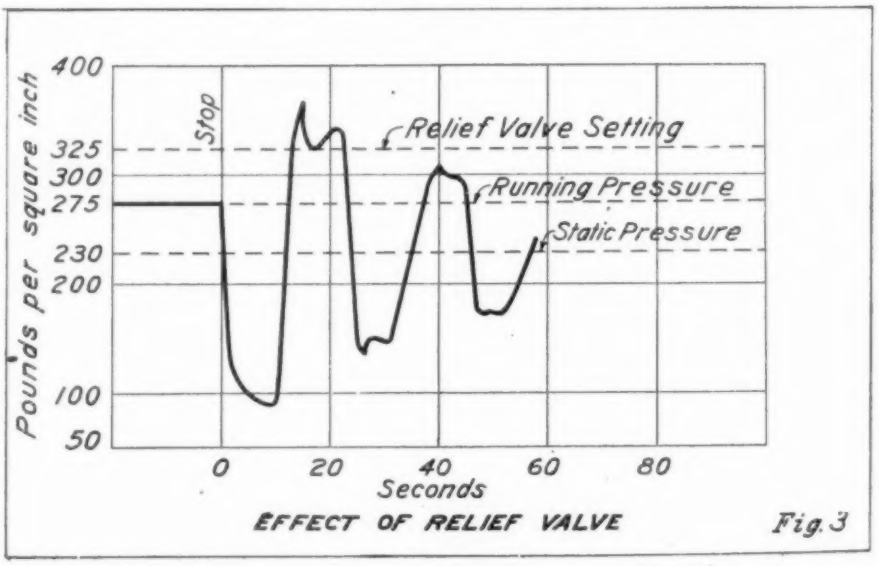


Fig. 3.—Graph Revealing Failure of Spring-Loaded Relief Valve to Relieve

The slope from E to F is due to the rise in friction pressure as the velocity away from the pump is gradually regained.

A comparison of the velocities and pressure as observed and those computed by Joukovsky's formula (Jour. Am. Water Works Assoc., 1904, p. 341); (W. W. and S., April, 1938, p. 338) is interesting.

Joukovsky's formula for waterhammer, produced by instantaneous valve closure, is:

$$H = \frac{aV}{g}$$

$$a = \frac{12}{\sqrt{\frac{w}{g}\left(\frac{1}{K} + \frac{D}{Ee}\right)}}$$

H = Head due to water-hammer, ft.
a = Velocity of water-hammer water, f.p.s.
V = Velocity of water in pipe, f.p.s.
g = Acceleration of gravity.
w = Weight of one cubic foot of water.
K = Bulk modulus of elastlcity of water, pounds per sq. in.
E = Modulus of elasticity of pipe material, pounds per sq. in.
D = Diameter of pipe, inches.
e = Thickness of pipe wall, inches.

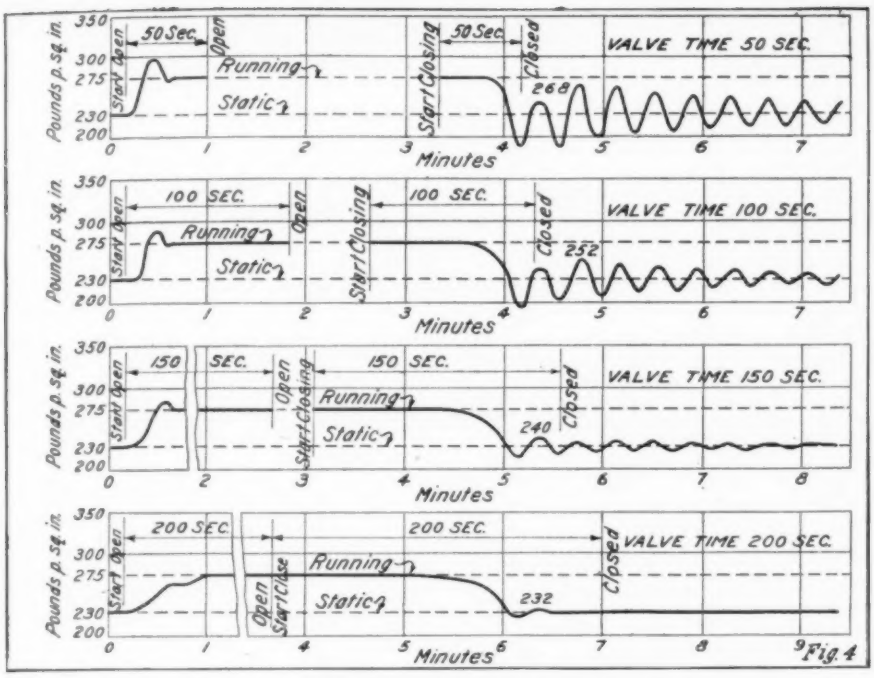


Fig. 4.—Graph Showing Results With a Cone Valve

The value of studying the effects of various closure times for surge suppression is effectively revealed in the four recorded graphs. A splendid testimonial as to the efficacy of properly controlled cone valves

The results are as follows:

Computed water-hammer head (negative)	326 ft.
Observed water-hammer head (negative)	322 ft.
Computed velocity of water-hammer wave	4220 f.p.s.
Observed velocity of water-hammer wave	4110 f.p.s.

If the pipe line had been shorter or the time of stopping longer so that the water-hammer wave set up by the first reduction in the discharge of the pump could have traveled to the end of the pipe and returned to the pump before the flow through the pump had stopped the returning supernormal wave would have interfered with the subnormal wave and the magnitude of the wave would have been reduced. So long as the returning wave does not reach the pump until its discharge is entirely stopped

$$t < \frac{aL}{2}$$

the result, for all practical purposes, is the same as that produced by an instantaneously closed valve. If it does return before the pump discharge has ceased, the interference of the waves must be considered. Except for this interference, the *water-hammer pressure is independent of the length of the pipe.* In the suction line which is only 400 feet long, the first wave returns in 0.2 of a second and interferes with the following waves, preventing, as stated before, the development of a pressure in the suction that might force water through the pump.

Relief Valves

When the Chazy Lake pumping station was built, a 4-inch spring loaded relief valve was installed on the 8-inch discharge line for the purpose of preventing any undue rise in pressure. This relief valve failed to produce the desired result. The effect of the relief valve on the water-hammer pressures is shown in Fig. 3. The inertia of the moving parts in the valve apparently prevents it from opening rapidly enough to relieve the pressure and the head rises almost to the same value that it does without the valve in operation. When it finally does release the water the pressure falls to that for which the valve is set. The valve then closes and stops the flow of water through it. The stopping of this flow sets up another water-hammer wave and the pressure again rises.

In order to satisfactorily prevent high pressures by means of a relief valve, the valve must open *before* the first returning wave reaches the pump. That is, before the pressure reaches the point D in Fig. 2. At this time the water in the line is flowing toward the pump and the pressure is the normal static pressure. If the valve is open at this time the water will flow out of the valve with no material rise in pressure. The valve must close slowly or the stopping of the flow through the valve will set up another water-hammer wave with consequent high pressures. It is generally necessary to provide an auxiliary source of power if this method of preventing high pressures is used because the pressure in the line is subnormal at the time the valve must start to open and usually insufficient to operate any type of valve.

This arrangement is used effectively at the Dalecarlia Pumping Station, Washington, D. C. (Water Works and Sewerage, April, 1938, Page 353). In this case the relief valve is of the hydraulically operated rotary plug type and the power for opening it is obtained from an independent water main near the station.

Air Chambers

The 8-inch by 96-inch air chamber provided on the discharge line from the pumps was found on test to be of absolutely no value in reducing the water-hammer pressures, and computations by the graphic method of Prof. Angus indicated that no reduction could be expected. An air chamber on the discharge line of a pump acts by supplying water to the line in gradually decreasing quantities after the pump has stopped, causing a gradual reduction in the velocity in the line instead of a suddenly closed valve.

To prevent high pressures in a pipe line by closing a valve slowly instead of rapidly requires that the time of closing be considerable, and if an air chamber is to be effective it must supply water to the line for a considerable time. Not only must the air chamber be large enough to contain sufficient water to

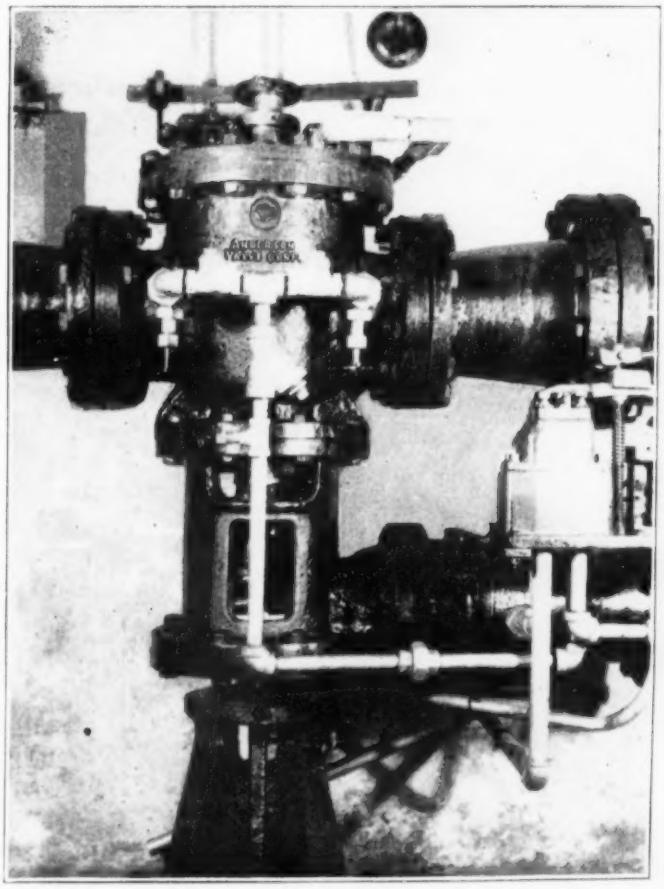


Fig. 5.—The Cone Valve
Which, with proper setting for closing time has solved the water-hammer problem

maintain this supply over the necessary period, but there must be sufficient air above the water to maintain the proper pressure on the water as the air expands. Air chambers, if they are to produce any measurable effect, must be far larger than those usually provided and often so large as to be impractical.

Cone Valve in Discharge Solves the Problem

The method now used at the Chazy Lake pumping station to eliminate the high water-hammer pressures is to reduce slowly the velocity in the discharge line before the pump being used is stopped—this instead of allowing velocity to be suddenly extinguished by the stopping of the pump. This is accomplished by a 6-inch hydraulically operated cone valve located in the main 8-inch discharge line near the pumps (see picture). The cone valve is in closed position when the pump is started. Since a centrifugal pump requires the smallest amount of power when operating against a closed valve, the motor thus starts under minimum load. As soon as the pump reaches its normal speed the cone valve slowly opens, the time of opening being controlled by the setting of a needle valve on the water feed-line to the hydraulic cylinder operating the cone valve. When it is desired to stop the pump the cone valve is first closed slowly, gradually reducing the velocity in the discharge main. After the valve is entirely closed the pump is stopped in the ordinary manner. Electrical interlocks are provided so that the attendant cannot change the order of the operations.

Results

The results of this method of operation, for different timings of the valve, are shown in Fig. 4. This valve rises from its seat before turning and reseats itself after completing its rotary motion. The time given for opening and closing is the time taken for the valve to rotate through 90 degrees, and does not include the time taken for unseating and seating. There is some leakage past the plug when it is raised from its seat, and the stoppage of this leakage by the seating of the valve in some cases causes a slight secondary wave, as is noticeable in some of the curves. The destruction of the velocity in the pipe line is, of course, not proportional to the amount of rotation of the valve as is evident from the fact that the first 2/3 of the revolution produces no measurable effect on the pressure. The effective closing time is therefore only a fraction of the actual closing time. Setting the valve to close in 50 seconds keeps the water-hammer pressure below the running pressure. Further increasing the time of closing reduces the water-hammer pressure until with a closing time of 200 seconds the excess pressure caused by water-hammer is scarcely noticeable.

At this pumping station only one pump should be operated at a time if economical results are to be obtained. Two pumps can, however, be operated at once with a consequent decrease in the delivery per pump and a decrease in efficiency. The water-hammer pressure produced by closing the cone valve with two pumps in operation is practically the same as that produced by closing the valve with one pump in operation, the time of closing being the same. The reason for this is that while the actual closing time is the same, the effective closing time, as indicated by the curves, is about twice as long with two pumps in operation.

This method of reducing water-hammer pressures does not protect the discharge line from water-hammer pressures due to power failure. Such protection can be afforded only by a properly timed relief valve operated by a separate source of power or by the use of an air chamber, both of which methods have been previously mentioned. In the case of the Chazy Lake pumping station, neither of these methods seemed practical because of the difficulty of securing a separate source of hydraulic or other power; and, the very large size of the air chamber required to produce even a small reduction in the excess pressure. At this station the water-hammer pressures do not rupture the pipe but do strain the lead joints, and the high pressures can be repeated several times before leaks occur. For these reasons, it was decided to protect the pipe line against the high pressures produced by the daily starting and stopping of the pumps, and to risk occasional high pressures due to power failures which may occur at very infrequent intervals.

Cylindrical Tank Capacities Per Foot of Depth

(The Cubic Foot Figure Is Also the Area in Each Instance)

Diam. Ft. In.	Contents Per Ft. Depth Cu. Ft.	Gals.	Diam. Ft. In.	Contents Per Ft. Depth Cu. Ft.	Gals.	Diam. Ft. In.	Contents Per Ft. Depth Cu. Ft.	Gals.	Diam. Ft. In.	Contents Per Ft. Depth Cu. Ft.	Gals.	Diam. Ft. In.	Contents Per Ft. Depth Cu. Ft.	Gals.
1	0.785	5.87	11-6	103.9	777.0	20	314.2	2350	32	804.3	6016	58	2642	19760
1-3	1.227	9.18	9	63.62	475.9	20-6	330.1	2469	33	855.3	6398	60	2827	21150
1-6	1.767	13.22	9-6	70.88	530.2	21	346.4	2591	34	907.9	6792	62	3019	22580
1-9	2.405	17.99	10	78.54	587.5	21-6	363.1	2716	35	962.1	7197	64	3217	24060
2	3.142	23.50	10-6	86.59	647.7	22	380.1	2844	36	1018	7616	66	3421	25590
2-3	3.976	29.74	11	95.03	710.9	22-6	397.6	2974	37	1075	8043	68	3632	27170
2-6	4.909	36.72	12	113.1	846.0	23	415.5	3108	38	1134	8483	70	3848	28790
2-9	5.940	44.43	12-6	122.7	918.0	23-6	433.7	3245	39	1195	8940	72	4072	30450
3	7.069	52.88	13	132.7	992.9	24	452.4	3384	40	1257	9404	74	4301	32170
3-3	8.296	62.06	13-6	143.1	1071	24-6	471.4	3527	41	1320	9876	76	4536	33930
3-6	9.621	71.97	14	153.9	1152	25	490.9	3672	42	1385	10360	78	4778	35740
3-9	11.04	82.62	14-6	165.1	1235	25-6	510.7	3820	43	1452	10860	80	5027	37600
4	12.57	94.00	15	176.7	1322	26	530.9	3972	44	1521	11370	82	5281	39500
4-6	15.90	119.0	15-6	188.7	1412	26-6	551.5	4126	45	1590	11900	84	5542	41450
5	19.63	146.9	16	201.1	1504	27	572.6	4283	46	1662	12430	86	5809	43450
5-6	23.76	177.7	16-6	213.8	1600	27-6	594.0	4443	47	1735	12980	88	6082	45490
6	28.27	211.5	17	227.0	1698	28	615.8	4606	48	1810	13540	90	6362	47590
6-6	33.18	248.2	17-6	240.5	1799	28-6	637.9	4772	49	1886	14110	92	6648	49720
7	38.48	287.9	18	254.5	1904	29	660.5	4941	50	1964	14690	94	6940	51920
7-6	44.18	330.5	18-6	268.8	2011	29-6	683.5	5113	52	2124	15890	96	7238	54140
8	50.27	376.0	19	283.5	2121	30	706.9	5288	54	2290	17130	98	7543	56420
8-6	56.75	424.5	19-6	298.6	2234	31	754.8	5646	56	2463	18420	100	7854	58750

VALVE AND PRIMER CORPORATION

30 WEST WASHINGTON ST., CHICAGO 2, ILL.

Apco Automatic Pump Primers — *Apco Automatic Air Relief Valves*

V-Apco Automatic Vacuum Primers

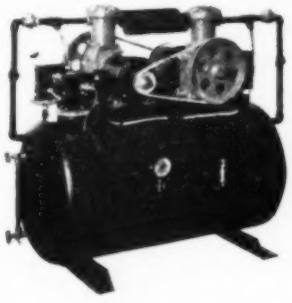
V-APCO Automatic Vacuum Primers and APCO Automatic Pump Primers

Advantages

V-APCO Automatic Vacuum Primers for centrifugal pumps offer these advantages: 1) Keep pumps always primed. 2) End loss of time due to lack of prime. 3) Operate at any vacuum under which the centrifugal pump will operate. 4) Uses no foot valve. 5) Flexible capacity; will serve additional pump installations satisfactorily. 6) Does not affect pump efficiency. 7) Improves operation of pump. 8) Simple design insures long life, freedom from trouble, highest efficiency.

How the Primer Operates

Drawing below shows the V-APCO Primer. A priming valve of the 200 series is placed on the vent of the centrifugal pump. While the vacuum pump is producing a vacuum, the valve passes all air that



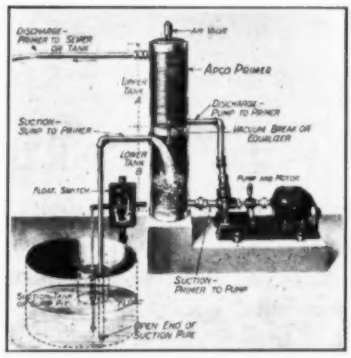
may be in the pump or suction line. When the air is withdrawn, it is followed by water which raises the valve float. That closes the outlet and prevents flooding of the vacuum pumps.

The Air Release Valve is mounted on the pump and connected to the vacuum storage tank that stores enough vacuum to act as a cushion on the vacuum pump. It provides a way to withdraw small amounts of air from the pump and suction lines from time to time. This makes frequent starting and stopping of the vacuum pump unnecessary.

A vacuum breaker on the vacuum tank unloads the vacuum pump in the unlikely event that is required. A vacuum switch with vacuum release connections is mounted on the vacuum tank and starts the vacuum pump when the vacuum drops in the storage tank and stops the pump when full vacuum has been reached. The vacuum release connection unloads the vacuum pump when it is not operating and places it in condition to start at no load.

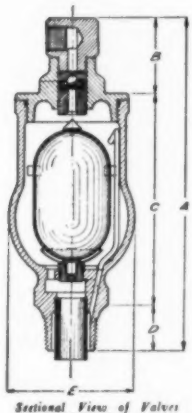
The check valve between the switch and the pump is a special noiseless one for the purpose, holding the vacuum in the storage tank when the pump is not operating.

THE APCO PRIMER

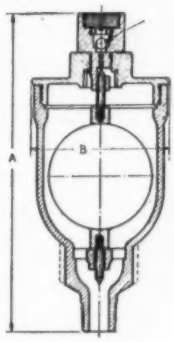


How the Apco Primer Works

This cut shows primer in service with the pump running. When the pump starts, it draws liquid from the lower chamber of the primer and discharges it through the upper chamber. The withdrawal of the liquid from the lower chamber creates a partial vacuum in this chamber which causes the liquid in the sump or well to rise in the suction pipe and flow through the primer to the pump. When the pump stops, the liquid in the upper chamber runs back through the pump into the lower chamber by gravity, thus refilling the lower chamber with liquid to prime the pump when it starts again.

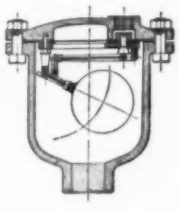


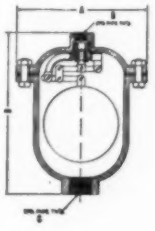
Sectional View of Valves Nos. 50-60 for Pressures Up to 60 Lbs.



Sectional View of Valve No. 50 H.D. for Pressures up to 150 Lbs.

Sectional view of Valve No. 200. The valve has large venting capacities and positive opening when under vacuum.

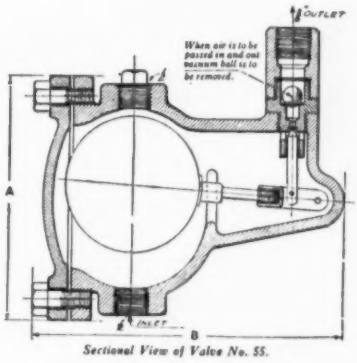




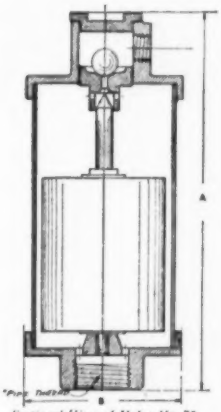
Sectional view of Valve No. 200-A.

APCO-Air Release Valves

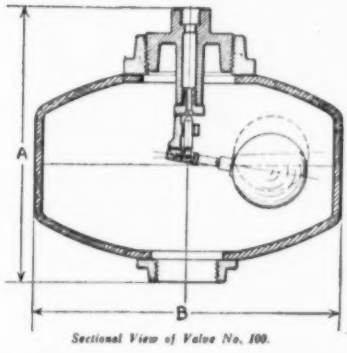
APCO Air Release Valves are made in 17 different sizes and capacities varying from the smallest with ⅜" pipe connection and small venting capacity to our large 2" size with an opening of 1" diameter and vacuum and air release valve from 2" to 6". We illustrate below a very few of these types. Your venting problems can be handled by some one of our valves in the proper manner. Prices are reasonable.



Sectional View of Valve No. 55.



Sectional View of Valve No. 70.



Sectional View of Valve No. 100.

THE Atlas Mineral PRODUCTS COMPANY OF PENNSYLVANIA

MERTZTOWN 12, PENNA.

*ATLANTA 3, Ga., 452 Spring St., N.W.
*CHICAGO 1, Ill., 333 N. Michigan Ave.
*DETROIT 2, Mich., 2970 W. Grand Blvd.
NEW YORK 16, N. Y., 280 Madison Ave.
PITTSBURGH 27, Pa., 4921 Plymouth Road
ST. LOUIS 8, Mo., 4485 Olive Street

THE ATLAS MINERAL PRODUCTS COMPANY of TEXAS, Inc., Box 252, HOUSTON 1, TEXAS

DALLAS 5, Tex., 3921 Purdue St.
*DENVER 2, Colo., 1921 Blake St.
*KANSAS CITY 2, Kan., 1913 Tauromee Ave.
*LOS ANGELES 12, Calif., 172 S. Central Ave.
OKLAHOMA CITY 2, Okla., 817 Braniff Bldg.
*HONOLULU 2, Hawaii, U.S.A., P.O. Box 2930
*SALT LAKE CITY 11, Utah, 925 So. 6th West St.
SAN FRANCISCO 7, Calif., 115 Townsend St.
*SEATTLE 4, Wash., 1252 First Ave., S.

Stock carried at these points

IN CANADA: H. L. BLACHFORD, LTD., 977 Aqueduct St., Montreal, P. Q.; 86 Bloor Street, W., Toronto, Ont.

Tegul-MINERALEAD JOINTING COMPOUND

FOR BELL & SPIGOT WATER MAIN

Tegul-MINERALEAD is a radically different jointing compound with advantages not matched in total in any other product for its purpose. Its sulphur base includes, as a plasticising agent, a special olefine polysulphide which contributes these advantageous properties: GREATER ADHESION TO METALLIC AND CERAMIC SURFACES • HIGHER RESISTANCE TO VIBRATION and to MECHANICAL SHOCK AND TEMPERATURE CHANGES • GREATER PLASTICITY and LOWER COEFFICIENT OF EXPANSION.

Using *Tegul*-MINERALEAD you may expect:

SPEED — *Tegul*-MINERALEAD melts, pours and sets quickly and uniformly (a factor in reducing labor costs). Joints show less than usual initial leakage and backfilling may start at once, thus hastening removal of traffic hazards which arise from open trenches.

CONVENIENCE — Molded in 10 lb. ingots, *Tegul*-MINERALEAD is easier to handle, ship and store. The ingot is impervious to moisture so may be stored outdoors in any weather. Since there can be no change of composition in an ingot, *Tegul*-MINERALEAD reaches you as correctly mixed as when it left our factory.

ECONOMY — *Tegul*-MINERALEAD weighs only 1/5th as much as lead (and goes 3 times as far) saving in shipping costs. 5 ingots to carton makes a handy package. It needs no caulking or deep bell holes and requires no skilled labor. The sum of *Tegul*-MINERALEAD'S advantages make it a *money-saver*, too.

RESISTANCE TO SHOCK — Higher resistance to mechanical and thermal shock promises permanently tight joints. Lines laid with *Tegul*-MINERALEAD in every kind of terrain and meeting every kind of punishment, have served for years without need of attention.

AVAILABILITY — *Tegul*-MINERALEAD is stocked at conveniently located points and is usually available on short notice. Using *Tegul*-MINERALEAD helps conserve lead, a strategic war metal.

HOW *Tegul*-MINERALEAD IS USED

MELTING — *Tegul*-MINERALEAD melts at 248°F., requiring only a slow fire. Care should be taken to avoid direct contact with flame and overheating, which tends to cause the compound to thicken. Best results are had by using furnace designed by the manufacturers of *Tegul*-MINERALEAD.

YARNING — The pipe at Bell and Spigot must be clean and free from accumulations of oil, tar and grease. If jute is employed it should be the dry, braided type.

POURING — See that joints are clean. Use mud on asbestos runner to prevent adhesion to the *Tegul*-MINERALEAD and to seal any leaks. Pour the melted compound slowly through a high pouring gate, using ladles or pouring pot of sufficient capacity to fill the joint at one operation. Add whole or half ingots to replace *Tegul*-MINERALEAD used. It is not necessary to wait for complete melting before pouring more joints. Cut off pouring gate when compound has solidified. Remove runner and joint is complete.

The HYDE-RO Ring

AN IMPORTANT AID IN BELL & SPIGOT JOINTING

***SPEEDS STERILIZATION*—First hypochlorite flushing invariably secures negative reaction.**

Cross section

PROMOTES ECONOMY — FACILITATES REPAIRS EASILY APPLIED

ADVANTAGES IN DETAIL . . .

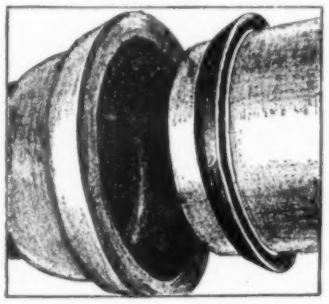
(1) PREVENTS CONTAMINATION — Rubber cannot harbor bacteria nor support their growth internally where water main sterilizing agents cannot reach them. The use of HYDE-RO Rings will prevent continued recontamination that has been traced in many cases to the joint packing.

(2) ECONOMICAL — The cost of HYDE-RO Rings is insignificant compared with the cost of repeated treatments with hypochlorite or the cost of sterilizing and keeping sterile (if it can be done), other types of packing.

(3) CONVENIENT — The installing of HYDE-RO Rings is a simple, easily understood operation. There is no measuring to be done and no cutting. The wrong size cannot be used. Since rings are solid, there are no laps to be inspected to see that they do not occupy too much of the joint space. The same ring fits pipe with bead on spigot or straight end pipe. The narrow iron blade used in caulking the ring automatically slips into the groove in the back.

(4) HOLDS BACK WATER — When HYDE-RO Rings are used, the pouring of wet joints is unnecessary. The rubber ring caulked tightly into place effectively dams off water from leaking valves and permits pouring of dry joints. This is especially important in repair work.

(5) CONVENIENT TO STORE — HYDE-RO Rings are supplied in cartons each containing fifty rings. The packages are light in weight and convenient to handle and store. Rings are manufactured for 4", 6", 8", 10" and 12" cast iron pipe.

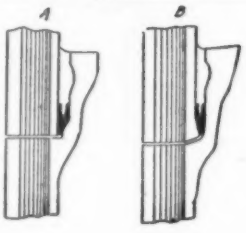


HOW RING IS USED

(1) Stretch the ring over spigot end of pipe with narrow end toward bell.

(2) Slide ring about 1½ inches from end of pipe; then slide the pipe home.

(3) Caulking the ring home, use narrow caulking tool about ⅛" or less in width.



Cross section showing the HYDERO Ring caulked into position on plain end (A) and beaded end (B).

We also manufacture
G-K—The Original Bituminous SEWER JOINT COMPOUND

Tegul—AMPCO JOINTING COMPOUND for Terra Cotta and Concrete SEWER PIPE

THE DISTRIBUTION SYSTEM*

Some Basic Considerations in Its Design, Maintenance and Operation

By L. R. HOWSON
Consulting Engineer
Alvord, Burdick & Howson, Chicago, Ill.

IN ENDEAVORING to appraise the importance of the distribution system in water works practice, I first turned to the Journals of the American Water Works Association, an inspection of which disclosed that there were over twice as many papers relating to water quality and water treatment as there were with reference to the distribution system, including meters, unaccounted for water, hydrants and valves. Probably this is as it should be, for water quality is a matter of life and death; whereas proper design, operation and maintenance of a distribution system is primarily a question of economics. Undoubtedly this seeming lack of proper consideration for the economics of water supply results from the inability of the various program committees to secure constructive papers on what is generally considered a prosaic subject.

Economic Value of Distribution Systems

As a second step in appraising the economic importance of the water distribution system, the summaries of 16 recent water works appraisals were analyzed. The analyses showed that for these 16 plants the distribution system valuation averaged 66.8 per cent of the total plant value. While this percentage varied somewhat for individual plants, all but two fell within a range of 20 per cent of this numerical average. The weighted average of the percentage of the distribution value to the total plant value of the 16 plants was 65.3 per cent. It may be roughly stated, therefore, that two-thirds of the total value of the average water works is found in the distribution system. A check of valuations made as remote as thirty years ago shows this ratio to have remained practically constant.

The fact that two-thirds of the value of the ordinary water works is in the distribution system, and that 80 per cent of the distribution system value is in the item of mains and valves, indicates one of the most valuable yardsticks for an approximate indication of the value of a water works property of which there is no detailed inventory available. The length of pipe of the various sizes in the distribution system is always a matter of record and capable of easy conversion into tons. Normally the weight of pipe in a cast-iron distribution system will approximate 275 to 300 tons per thousand population.

Analysis of nine recent water works valuations, most of which involved transfer of ownership, revealed that the value of the entire system per ton of pipe in the distribution system was approximately $200. Cities with well supplies or without treatment will normally fall somewhat under the $200 per ton, and those with impounded supplies and costly purification works will be normally somewhat above the $200 per ton figure. The application of this figure, however, varied with respect to the facts relating to the source of supply in each particular case, will give a convenient and very approximate indication of the valuation of the entire water works property at the present time.

An analysis of these same nine water works valuations showed that the average per capital value as of the present time was $63. Since two-thirds of the value of a water works system is normally in the distribution system, it is apparent that the present-day distribution system in the average city has a value equivalent to about $40 per capita.

Some Basic Factors in Design

Too many distribution systems just grow. Very few distribution systems were scientifically designed originally; and through growth, concentration and shifting demands most systems need almost constant checking. The problem of designing an entirely new distribution system is seldom met in practice. The more frequent problem is that of designing a feeder or circulating system to correct deficiencies in capacity resulting from growth, reduction in carrying capacity, or allied causes. The National Board of Fire Underwriters, through periodic tests of distribution systems, has done much to uncover weaknesses and to indicate the requirements for reinforcement.

Every water distribution system supplies two distinct services; namely, the furnishing of normal domestic and industrial requirements and the water required to fight fires.

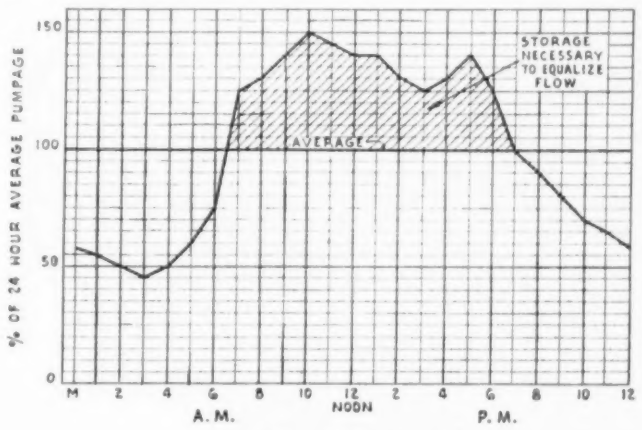
The former type of service extends more or less continuously over the entire area served. Fire demands are intermittent, concentrated in relatively small areas and of high intensity.

The domestic and industrial needs for water vary from day to day and from hour to hour. Ordinarily the maximum day of the year will be 50 per cent more or less in excess of the average day for the year, and on that maximum day, the peak hour will be 50 per cent more or less above the 24-hour average. Accordingly, the annual peak is approximately 2¼ times the average rate for the year. These percentages are subject to material variations for various cities but are sufficiently accurate for use in illustrating the comparative importance of ordinary and fire demands on the distribution system.

Elevated Tank Storage

The fact that the maximum rates prevail during but a portion of the day makes it possible to provide for them in whole or in part by storage in reservoirs or elevated tanks. Ordinarily, if elevated storage of from 20 to 40 gallons per capita (gpc.) is available, the rate of pumpage can be constant throughout the 24 hours of the day with all peaks met with water drawn from storage. It is, however, not necessary to provide storage in this amount to secure most of the benefits. Storage in the amount of but 25 per cent of the total storage requirement will ordinarily result in lowering the peak rate of pumpage by half its excess over the daily average. This 25 per cent storage provision is equivalent to only 5 to 10 gallons storage per capita.

Elevated tank storage sufficient to completely iron out hourly peaks is not very costly. Assuming 30 gpc. as the storage required in order that the supply and pumping equipment may operate at a uniform rate throughout the 24 hours of the day, the approximate present-day costs would be as follows:



Typical Hourly Pumpage Rates

Population	Elevated Tank Capacity	Elevated Tank Cost @ 12c/lb.	% Tank Cost to Value of Distr. System
5,000	150,000	18,000	9
25,000	750,000	69,000	6.9
50,000	1,500,000	132,000	6.6
100,000	3,000,000	250,000	6.25
200,000	6,000,000	500,000	6.25

The most of adequate elevated storage is thus from $2.50 to $3.60 per capita. Interest and depreciation at 6 per cent on this cost for municipal plants is but from 15 to 22 cents per capita per year, the equivalent of from 25 to 35 per cent of the average power cost where pumping is by electricity. Ability to avoid peak demand charges will frequently cover much of the fixed charges on the investment in elevated storage. The other benefits such as more uniform pressures, better operations of pumping

*A paper presented before the Wisconsin Section of A.W.W.A., the publication of which has been authorized by the Association.

equipment and safety against power outages, amply justify elevated storage in most water systems. The amount of elevated storage in each case is, of course, dictated by the individual conditions. The above is simply indicative of the possibilities to be developed.

Firefighting Considerations and Storage Costs

In addition to meeting all variations in domestic, commercial and industrial demands, a distribution system must be so designed as to transport the volume of water required for fighting fires. The rate at which water is required for fire service is a reflection of the character of development, whether suburban or metropolitan, fire hazards, and so forth. It varies approximately as the square root of population in thousands and is, therefore, proportionately greater for smaller communities. The following table gives the amount of water required by the National Board of Fire Underwriters for fighting fires in cities of various sizes:

Population	Fire Demand (GPM)
5,000	2,250
25,000	4,750
50,000	6,500
100,000	9,000
200,000	12,000

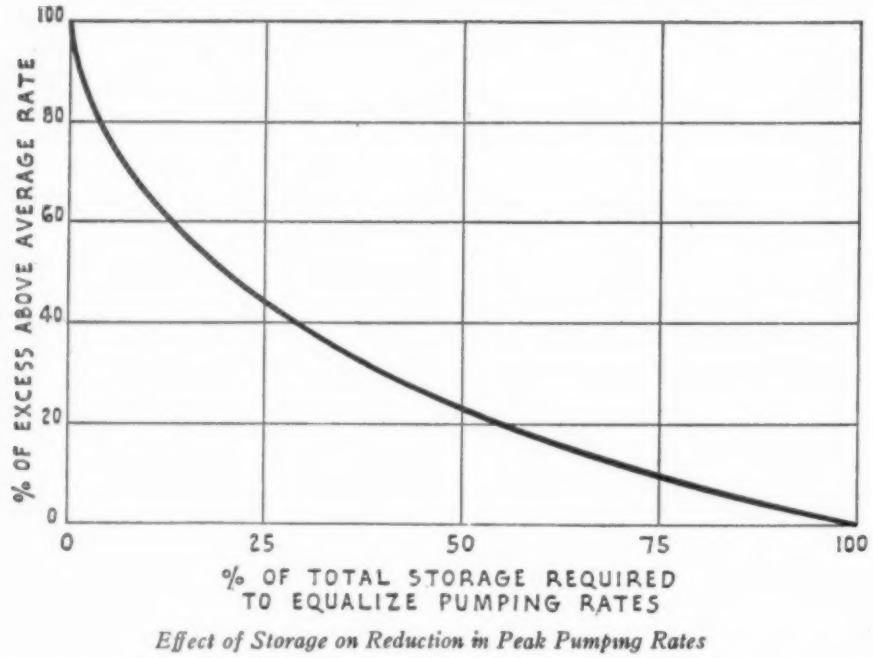
The above quantities are required in addition to the ordinary uses at the time, usually considered as 150 per cent of the average for the 24 hours.

Fortunately, fires do not occur at frequent intervals but they do occur with sufficient frequency and intensity to demonstrate the wisdom of making adequate provision for them. The extinguishment of fires ordinarily uses less than one-half of 1 per cent of the total pumpage.

The fact that fires are relatively of short duration indicates the possibility of storage to provide the water required for fighting fires, thus avoiding sudden extreme drafts upon water production systems. The accompanying table shows the fire demand rate, the volume of water required during 10 hours at the several rates (Underwriter's requirement), and the estimated cost of reinforced concrete reservoir construction to store the fire requirements for cities of various populations; and the ratio of reservoir cost to distribution system value.

Population	10 Hour Fire Use (Gallons)	Cost of Reinforced Concrete Reservoir*	Ratio of Reservoir Cost to Distribution System Value
5,000	1,350,000	$ 55,000	27.5%
25,000	2,750,000	93,000	9.3%
50,000	3,900,000	113,000	5.65%
100,000	5,400,000	135,000	3.37%
200,000	7,200,000	158.000	1.97%

*To store fire requirement—such costs being based on E.N.R. Construction Cost Index = 250.



Effect of Storage on Reduction in Peak Pumping Rates

If the topography is such that reservoir storage equal to the fire use can be so located as to float on the distribution system, it will relieve the source of supply, pumping equipment and distribution system of the fire demand and thus affect the total valuation of $63 per capita. It is also available and useful for domestic peaks at all times without cost other than interest and depreciation on the investment.

If the reservoir is built at ground level comparable to the station, but at a point near the opposite end of the distribution system from the pumping station, it is of value to the source of supply and the mains but duplicate pumping equipment will be required. A reservoir of this kind benefits about 90 per cent of the plant valuation when used during fire, but is of less value during other periods as booster pumps must be operated to make its benefits available.

If the water required to fight fires is stored in a low service reservoir or clear well at the pumping station, its effect is limited to the source of supply; i.e., usually less than 25 per cent of the property valuation.

An elevated tank to store the quantity of water required for fire in a 5,000 town would cost about $115,000. Since such a figure represents about 60 per cent of the value of the entire distribution system, it is evident that the primary justification for the elevated tank in the smaller systems is in equalizing hourly variations in domestic use.

The ratio of the water required for fire protection, and for peak domestic uses, is shown as follows:

Population	Peak Domestic Rate @ 225% of 100 gpc/day	150% Domestic plus Fire	Ratio Fire to Domestic Peak
5,000	1,125,000	4,250,000	3.7
25,000	5,625,000	10,600,000	1.88
50,000	11,250,000	17,000,000	1.51
100,000	22,500,000	27,900,000	1.24
200,000	45,000,000	47,300,000	1.05

It will be noted that for a city of 5,000, the peak demand during fire, which is based upon the fire use plus 150 per cent of the average day domestic, is 3.7 times as great as the peak hour domestic use; decreasing progressively to 1.88 for 25,000 population, 1.51 for 50,000, 1.24 for 100,000, and 1.05 for 200,000. In other words, for a city of approximately 200,000 population or larger, the peak domestic use rather than the fire requirement determines the size of the distribution system. For all populations less than 20,000 the fire requirement is the governing factor in the design of the distribution system.

Sizes of Mains

A water works distribution system consists of feeder mains and lateral distributors to serve consumers. The proportion of the total flow during fire which is carried through the laterals may vary from a negligible amount where the lateral system consists of 4-in. mains or smaller to a material proportion where the lateral distributors are 6-in. or larger. In order to ascertain how the pipe sizes vary in the average distribution system, the pipe systems of eight cities varying in population from 5,000 to 300,000 were studied. In the average of these systems, approximately 55 per cent of the mileage of mains was 6-in. in diameter with 15 per cent 4-in., another 15 per cent 8-in., and about half of the remainder 12-in. The weighted average size obtained by multiplying the footage of each size by its diameter and dividing the sum of the totals by the lineal feet, is approximately 7-in. This weighted average diameter varied but little between the eight systems, the maximum variation being not more than 5 per cent either way.

A few cities such as Des Moines, Iowa, have in recent years adopted 8-in. as the minimum size to use, in which case the proportion and capacities of feeder mains is less and the weighted average size of the mains larger. However, in very few cities does the weighted average size of mains materially exceed 7-in.

Larger diameters of pipe provide more carrying capacity per dollar expended, as is shown by the following table:

Diam. of pipe	Comparative Carrying Capacity*	Cost per foot Installed	Relation of cost to Capacity
4"	100	$1.10	1.1
6"	292	1.50	.52
8"	620	1.95	.31
12"	1,800	3.10	.17
16"	3,850	4.60	.12
20"	6,950	6.35	.09

*Based upon C = 120 of Hazen-Williams formula and pressure drop of 8 ft. per 1,000 ft.

The above estimates of cost are based upon Class B pipe at $50 per ton and costs of laying, which were the average of those used in six recent mid-western appraisals.

From an analysis of the above, it is apparent that a 6-in. main costs about 36 per cent more than a 4-in., but with the same friction loss will deliver 192 per cent more water. Correspondingly, an 8-in., which costs 30 per cent more than 6-in., will deliver 112 per cent more water, and a 12-in., which costs 59 per cent more than an 8-in., will deliver 191 per cent more water. Expressed in another way, increasing the pipe diameter by one size increases the carrying capacity from three to four times as much as the proportionate increase in cost.

Effect of Elevated Storage on Expenditures for Feeder Main

As a general line of demarcation it may be assumed that, in the ordinary distribution system, mains 6-in. in diameter and smaller primarily serve the normal domestic requirements; and that mains 8-in. and larger, in addition to serving these requirements, have been so designed as to provide a circulatory or feeder system to carry the water from the pumping station or reservoirs to the smaller distributing mains. The beneficial effects of elevated storage are, therefore, primarily limited to mains 8-in. and larger.

As stated, approximately 70 per cent of the footage of mains in the average distribution system is 6-in. or less in diameter. However, the mains of larger diameter cost more per foot, and an analysis of a considerable number of distribution systems shows that approximately 45 per cent of the value of the distribution system is in mains 8-in. and larger.

The value of the mains over 8-in. in diameter in the average distribution system is approximately $15 per capita.

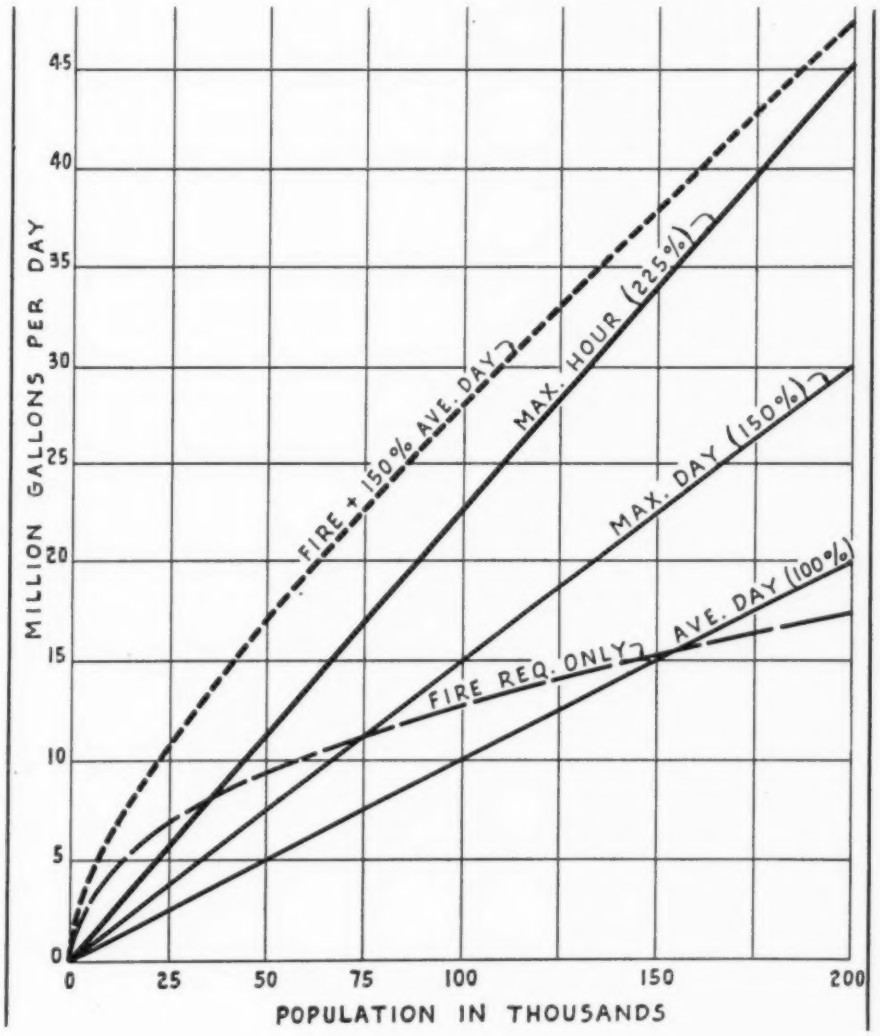
This value may be developed from the above figures on (1) the value of the average entire water works system at the present time, (2) the proportion of that value which is in the distribution system, (3) the proportion of the distribution system which is accounted for by mains, and (4) the percentage of total main value in mains larger than 8-in. In a city of 25,000 people the value of mains 8-in. and larger might be expected to be approximately $375,000.

Elevated storage sufficient to iron out the daily variations in flow in the average city of 25,000 population would cost approximately $69,000 at the present time, the equivalent of 18 per cent of the investment in feeder mains 8-in. and larger. If the topography is such that this peak requirement could be stored in a concrete reservoir at sufficient elevation, and not too distant, it would cost $36,000. This is less than 10 per cent of the investment in feeder mains.

There is obviously no general rule that can be laid down as applicable to all cities. In a recent study for a city where topography is such that strategically located reservoir storage could be provided within the area served by the distribution system, the provision of storage sufficient to provide for both domestic peaks and fire requirements cost approximately 30 per cent of the investment in feeder mains, and less than the expenditures required without storage for the proper reinforcement of the feeder main system.

Loss in Carrying Capacity

Another factor which has had a large effect on distribution system design has been the necessity of anticipating a loss in carrying capacity with the passage of time. The extent of this loss was evaluated by Edgar K. Wilson (Jour. AWWA, Vol. 28, No. 9), who showed that for midwestern waters in general, the Hazen-Williams coefficient decreased from 130 when new to 100 in about 20 years; a loss averaging more than one per cent per year. If such loss in carrying capacity were reflected in a comparable loss in valuation, this would be equivalent to a per capita loss of approximately $10 in a 20-year period, or 50 cents per capita per year, or nearly 10 per cent of the gross revenues of the average water utility.



Water Demand Rates
Domestic, 24-Hour Fire and Combined Fire and Domestic

Fortunately, this loss in carrying capacity is not correspondingly reflected in value. It is practicable to restore the carrying capacity to substantially its initial value by cleaning. Taking the average distribution system, the cost of such cleaning is approximately 5 per cent of the cost of the pipe installed new. Cleaning an entire system is seldom, if ever, resorted to. When main cleaning is done, it is usually confined to the feeder and circulating pipes where relation of cleaning to installation cost is even less than 5 per cent.

Loss of capacity, however, is a serious indictment of the water works industry. Certainly some method of protecting so large a proportion of the total water works investment should be available at reasonable cost. It is rather surprising that the heavier cement linings have not been more largely adopted. The cost of heavy cement lining varies from 6½ cents per ft. for 6-in. pipe to 26 cents per ft. for 20-in. pipe, equivalent to approximately 5 per cent of the cost of the pipe installed. If its use will maintain the carrying capacity of pipe (as seems probable

in most cases) its cost is well justified. Many designers have figured pipe sizes using Hazen-Williams coefficient of 100 instead of 130, in anticipation of loss in capacity. The cost of this excess capacity exceeds that of cement lining. Cement lining costs about the same as one cleaning but is better because it maintains capacity, whereas cleaning only periodically restores it. However, it is now possible to cement line mains in place after the cleaning operation.

Data regarding the maintenance of the coefficient of carrying capacity of cement-lined pipe are not so plentiful as for tar-coated pipe. The Cast Iron Pipe Research Association endeavored to secure such data by testing 42 cement-lined cast-iron pipe lines in 12 cities, located principally in the active or tuberculating water areas. All but eight of these mains had been in service from 10 to 16 years. The Hazen-Williams coefficient varied from 131 to 153, indicating little if any loss in coefficient value. Had these mains been tar-coated, it is believed the coefficient would have approximated 110.

The failure to adopt this improved coating more generally would appear to result from the average water works man's opinion that cast-iron mains, with the usual tar coatings, can be used in hard water areas without deterioration in carrying capacity. It is believed, by and large, that is not the case. It is suggested that, prior to the beginning of any important expansion of a distribution system, comprehensive flow tests be run and the relation between years of service and the Hazen-Williams coefficient be determined. If the loss is at all material, consideration of cement lining is suggested.

Unaccounted-for Water

There has been a greatly increased interest in "unaccounted for water" in recent years. As recently as 15 years ago, the average completely metered, well administered water works accounted for less than 75 per cent of the water used. At the present time that percentage is about 85 per cent, with a very few cities exceeding 90 per cent. One city of approximately 150,000 people, which had been completely metered for 40 years, was accounting for but slightly more than 60 per cent of the water pumped. By careful attention to its meters, their repair and accuracy of registration at low flows particularly, the accounted for water in this system has now been brought up to 83 per cent. The utility is now being paid for 35 per cent more water than before the improved meter maintenance program was started. The principal change was to see that all meters would register the low flows.

It is believed that the most important factor in reducing the quantity of water unaccounted for is the careful maintenance and repair of meters, with particular emphasis placed upon the accuracy of registration at low flows. Instead of referring to 15 to 25 per cent unaccounted for water, it has been suggested by Mr. A. P. Kuranz, Supt. of Water at Waukesha, Wis., that the unaccounted for water be visualized in terms of the equivalent waste of two to three months' coal, power and chemicals each year. In Mr. Kuranz's plant he has reduced the unaccounted for water to less than 7 per cent, an illustration of what can be done.

Water waste control, however, requires more than attention to the meters. It includes the necessity of locating leaks promptly and repairing them immediately. Every facility must be used to locate the hidden leaks, such as watching for melted spots on the streets during periods of light snow and listening at meters, valves and hydrants when routine inspections are being made.

Hydrants

Hydrants should be inspected at least twice each year, at which times they should be operated and checked for the operation of the drip, free draining, condition of packing etc. They should also be carefully inspected after each use in the cold weather months. Each hydrant, too, should have a card on which should be recorded everything done to the hydrant, including each semi-annual inspection and what was observed at that time. Such a record is invaluable in case attempt is made to fix liability for a non-operative hydrant which may result from an attempt to open in the wrong direction, mishandling or some other cause.

It is good practice to install hydrants farther back from the curb and street corners than was formerly the practice before the use of the automobile became universal. It is also good practice to have a shut-off gate valve on every hydrant connection.

Hydrants should never be operated by other than the fire department or water works employees. The occasional use of fire hydrants to fill sprinkling wagons, and to flush sewers and streets, is bad practice. It jeopardizes the ability of the water system to function when most needed. In one city, where hydrant wrenches were too freely distributed, the annual cost of maintenance and repair was over $8 per hydrant as compared to an average of less than $3. The number of hydrants replaced, in proportion to those in use, was double that of other cities where the use of hydrants was properly restricted.

Valves

Valves should be inspected at regular intervals. If all valves do not open in the same direction, all exceptions should be recorded and their existence emphasized. Every valve should have a number and a card on which pertinent data relative to its location, installation, repair and maintenance are included. All valves should be provided with means of access, and it is good practice to install valves 12-in. and larger in vaults. Packing of valves should be inspected and adjusted when necessary.

Valves should be spaced at intervals of 500 to 800 ft. and so placed that no break will take more than two blocks of pipe out of service.

Distribution Maps

Too many water works either have no adequate map records or they are not kept up to date. A wall map should be available, of such scale as to make it usable. There should also be a sectional atlas of the entire pipe system on sheets about 24x36 in. and scale of 50 ft. or 100 ft. to the inch, with intersections and other congested areas enlarged when necessary.

RELATIVE SIZES OF BRANCHES AND WATER MAINS

Size of Main	Number and Size of Branches Main Will Supply—Running Full
½"	Two—⅜"
¾"	Two—½"
1"	Two—¾"
1¼"	Two—1" *or* One—1" and Two—¾"
1½"	Two—1¼" *or* One—1¼" and Two—¾"
2"	Two—1½" *or* One—1½" and Two—1¼"
2½"	Two—1½" and Two—1¼" *or* One—2" and Two—1¼"
3"	One—2½" and One—2" *or* Two—2" and Two—1½"
3½"	Two—2½" *or* One—3" and One—2" *or* Four—2"
4"	One—3½" and One—2½" *or* Two—3" *or* Three—2½" and One—2" *or* Six—2"

CURVE FOR DETERMINING FLOW IN COMPONENTS OF PARALLEL PIPE SYSTEMS

By JOHN J. BAFFA
Consulting Engineer
New York City

THE calculation of flow available through each component of parallel pipe systems is often necessary for distribution system reinforcement problems and for new system designs. The accompanying curve readily permits the calculation of the percentage of total flow for each element of two pipe or multiple pipe parallel systems. The curve is based upon the use of "flow resistance factors" for the determination of relative resistance to flow of each component. The "flow resistance factors" are those commonly used with the Hardy Cross method of analysis.

It is believed that the use of this curve and the formulae connected therewith are of value in permitting the designer to deal with the actual physical elements involved in a problem. A direct approach toward the solution of many practical small-system problems is thus provided since the effect, on the system as a whole, of an alternate pipe size, pipe lining, main cleaning or coefficient depreciation for any component may be readily evaluated by reason of change in its "flow resistance factor."

Derivation

The fundamental law of flow is taken to be the familiar:

$$h = r\,Q^n \qquad \text{Eq. (1)}$$

where h = head loss in feet per 1000
r = flow resistance factor
Q = discharge in gallons per minute
n = 1.85 (Hazen and Williams value)

In Table I are given the values of $r \times 10^5$ for 1000 feet of main with Q in gallons per minute.

In Fig. 1 is shown a two pipe parallel system. Each leg in turn comprises three elements of different flow resistance value. The total resistance for path No. 1 is

$$r_1 = r_a + r_e + r_f \qquad \text{Eq. (2)}$$

and for path No. 2 is

$$r_2 = r_a + r_b + r_c \qquad \text{Eq. (3)}$$

The percentage of total flow which will travel through path No. 1 is

$$P_1 = \frac{Q_1}{Q} \times 100 \qquad \text{Eq. (4)}$$

and for path No. 2 is

$$P_2 = \frac{Q_2}{Q} \times 100 \qquad \text{Eq. (5)}$$

Since the head loss between inlet and outlet is the same for both paths, it can be demonstrated by simple algebra that

$$P_1 = \frac{1}{1 + \left(\frac{r_1}{r_2}\right)^{\frac{1}{n}}} \qquad \text{Eq. (6)}$$

$$P_2 = \frac{1}{1 + \left(\frac{r_2}{r_1}\right)^{\frac{1}{n}}} \qquad \text{Eq. (7)}$$

Thus the curve in Fig. 5 is plotted with ratios $\frac{r_1}{r_2}$ as abscissas and percentages of flow through paths No. 1 as ordinates. The curve is set up so that the path with least resistance should always be considered as path No. 1, or, in other words, so that the value of r_1 divided by r_2 is always a fraction. This procedure eliminates the necessity for extending the abscissa scale for values greater than 1.0 and permits greater accuracy of curve reading for page size requirements. The curve in the upper right hand corner of Fig. 5 represents enlargement of that portion of the parent curve for resistance ratios between zero and 0.10.

Example

Fig. 2 shows diagrammatic representation of a typical problem. It is required to find Q_1 and Q_2. The total flow resistance factor for Q_2 is $r_2 = 4.82 + 3.00 + 0.60 = 8.42$ and the total flow resistance factor for Q_1 is

$$r_1 = 1.70 + 1.20 + 0.17 = 3.07$$

The factor ratio $\frac{r_1}{r_2}$ is $\frac{3.07}{8.42} = 0.36$. From the curve, Fig. 5, with a resistance factor ratio of 0.36 the percentage of flow that will follow the path of least resistance is 63.2 per cent, so that Q_1 equals 632 gpm. and Q_2 equals 368 gpm.

With the flows determined, the head loss for each element may, of course, be readily obtained from the Hazen and Williams tables or directly from the relationship

$$h = rQ^{1.85}$$

utilizing table of the 0.85 power of numbers.

Systems With More Than Two Branches

For systems with more than two branches a similar solution is possible. For the system shown in Fig. 3 the head loss between common inlet and common outlet is

$$H = RQ^n \qquad \text{Eq. (8)}$$

where R is the total overall resistance factor for the system. It can be demonstrated by simple algebra that for m pipes in parallel

$$\frac{1}{R^{\frac{1}{n}}} = \frac{1}{r_1^{\frac{1}{n}}} + \frac{1}{r_2^{\frac{1}{n}}} + \frac{1}{r_3^{\frac{1}{n}}} + \ldots \frac{1}{r_m^{\frac{1}{n}}} \qquad \text{Eq. (9)}$$

Thus for the system in Fig. 3 equation 9 may be written as

$$\frac{1}{R^{\frac{1}{n}}} = \frac{1}{r_1^{\frac{1}{n}}} + \frac{1}{r_{23}^{\frac{1}{n}}} \qquad \text{Eq. (10)}$$

wherein

$$\frac{1}{r_{23}^{\frac{1}{n}}} = \frac{1}{r_2^{\frac{1}{n}}} + \frac{1}{r_3^{\frac{1}{n}}} \qquad \text{Eq. (11)}$$

Thus

$$P_1 = \frac{Q_1}{Q} \times 100 = \frac{1}{1 + \left(\frac{r_1}{r_{23}}\right)^{\frac{1}{n}}} \times 100 \qquad \text{Eq. (12)}$$

$$P_{23} = \frac{Q_2 + Q_3}{Q} \times 100 = \frac{1}{1 + \left(\frac{r_{23}}{r_1}\right)^{\frac{1}{n}}} \times 100 \qquad \text{Eq. (13)}$$

$$P_2 = \frac{Q_2}{Q} \times 100 = P_{23} \times \frac{1}{1 + \left(\frac{r_2}{r_3}\right)^{\frac{1}{n}}} \qquad \text{Eq. (14)}$$

$$P_3 = \frac{Q_3}{Q} \times 100 = P_{23} \times \frac{1}{1 + \left(\frac{r_3}{r_2}\right)^{\frac{1}{n}}} \qquad \text{Eq. (15)}$$

Equation 11 is readily solved by a chart prepared by J. R. Arbuthnot (Ref. 2) or with tables of the 0.54 and 0.85 powers of

TABLE I

Values of r for 1000 Feet of Pipe Based on the Hazen-Williams Formula

Pipe Diameter, Inches	C = 90	100	110	120	130	140
4	300	248	208	177	153	133
6	41	33.7	28.4	24.2	20.9	18.2
8	10	8.4	7.0	6.0	5.2	4.5
10	3.4	2.8	2.4	2.0	1.7	1.5
12	1.5	1.2	1.0	.83	.71	.62
14	.66	.55	.46	.39	.34	.30
16	.35	.29	.24	.20	.18	.15
18	.20	.16	.14	.12	.10	.09
20	.12	.10	.08	.07	.06	.05
24	.049	.04	.03	.03	.02	.02
30	.016	.013	.011	.010	.008	.007
36	.0067	.0054	.0046	.0039	.0034	.0030

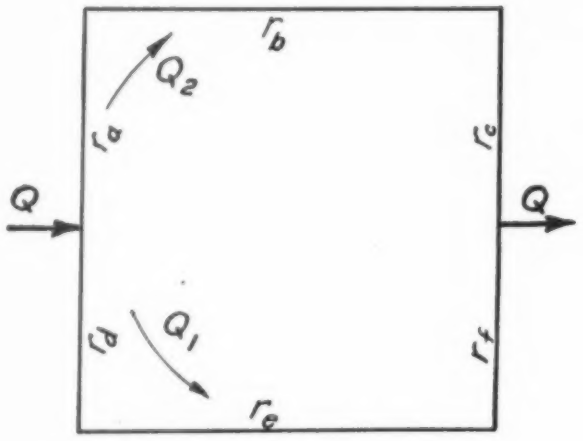


Figure 1

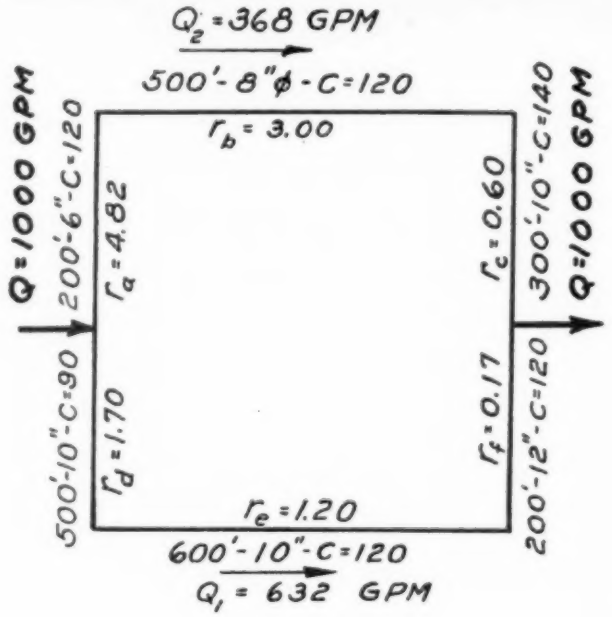


Figure 2

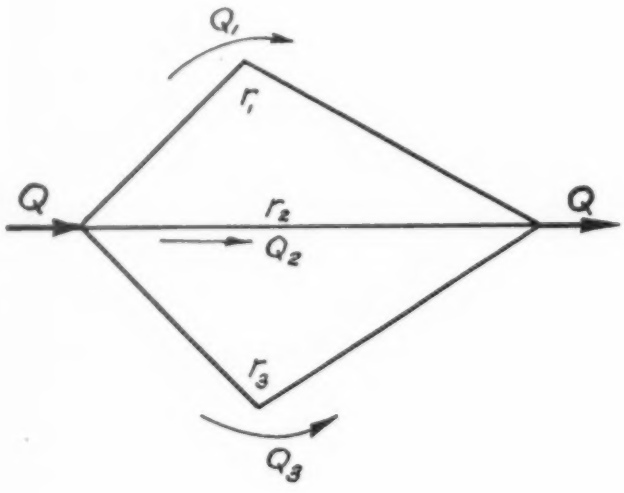


Figure 3

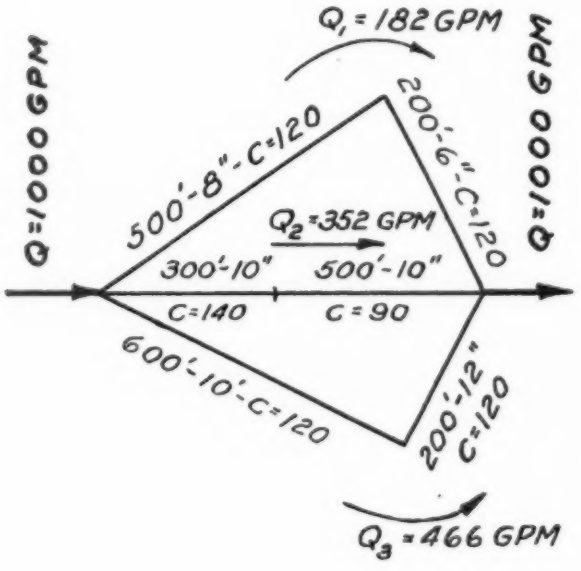


Figure 4

Figs. 1-4. *Examples of Parallel Pipe Systems*

numbers. The percentages for determinations of flows for each branch can be read directly from the curve in Fig. 5. As indicated by the above equations, the three branch system is considered as a two branch system comprising one single pipe leg and one double pipe leg and the double pipe leg comprising a two branch system. Similarly a four branch system can be considered as comprising two two-branch systems in parallel, and so on.

Example

Fig. 4 shows diagrammatic representation of a typical problem. It is required to find Q_1, Q_2 and Q_3.

$$r_1 = 3.00 + 4.82 = 7.82$$
$$r_2 = 0.60 + 1.70 = 2.30$$
$$r_3 = 1.20 + 0.17 = 1.37$$

$$\frac{1}{(r_{23})^{0.54}} = \frac{1}{(2.30)^{0.54}} + \frac{1}{(1.37)^{0.54}}$$

$$r_{23} = 0.48$$

$$\frac{r_{23}}{r_1} = \frac{0.48}{7.82} = .061$$

From Fig. 5

$$P_{23} = 81.8\%$$

Therefore

$$Q_3 + Q_2 = 818 \text{ gpm.}$$
$$Q_1 = 182 \text{ gpm.}$$

From Fig. 5 read 56.9 per cent for

$$\frac{r_3}{r_2} = \frac{1.37}{2.30} = .594$$

Hence $Q_3 = 0.569 \times 818 = 466$ gpm.
$Q_2 = 818 - 466 = 352$ gpm.

References

(1) The Hardy Cross Method. By D. R. Taylor, *Waterworks & Sewerage* Reference and Data, 1943.
(2) Chart for Determination of Equivalent Pipes. By J. R. Arbuthnot, *Water & Sewage Works*, August, 1946.

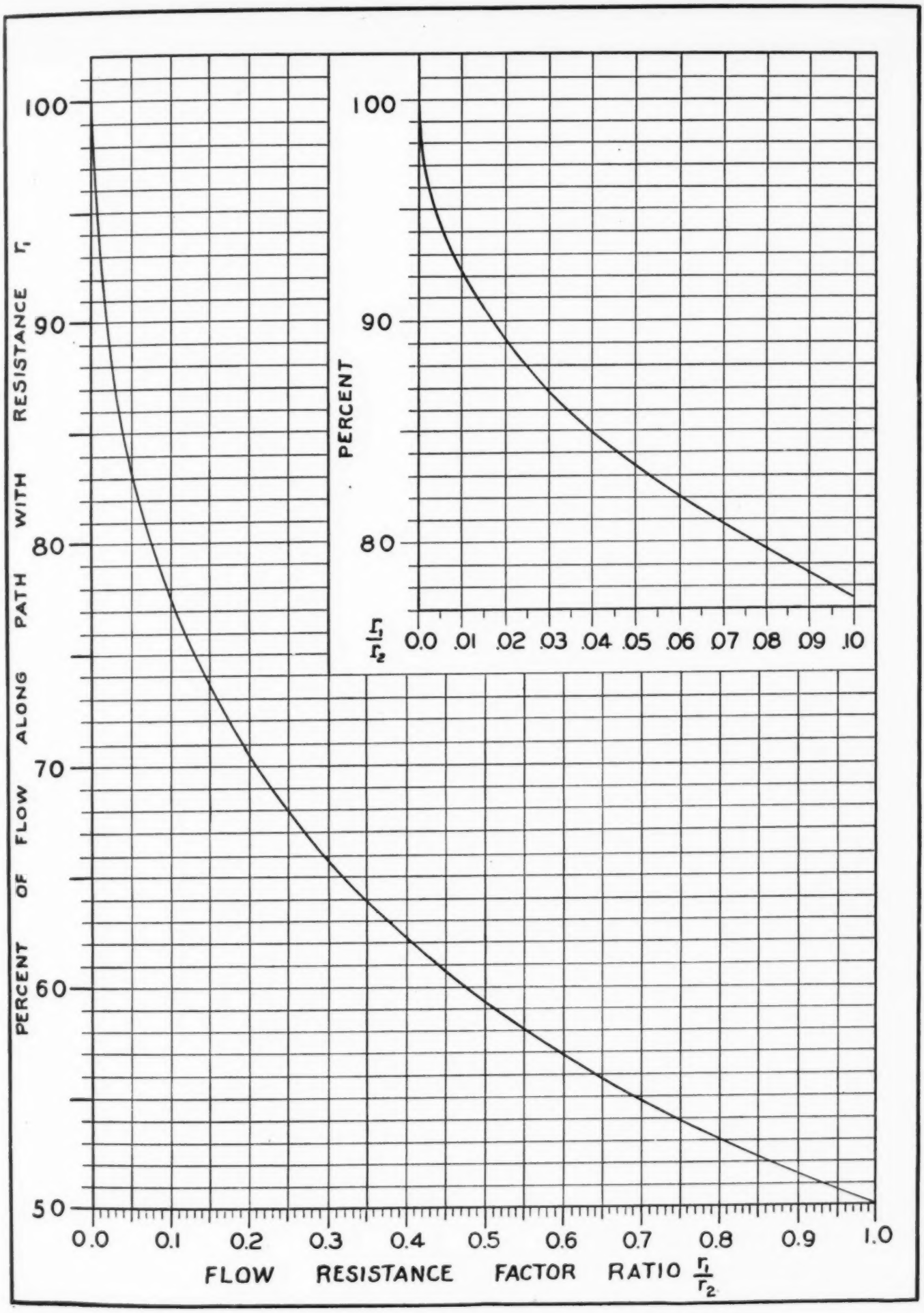


Fig. 5. Curve for the Determination of Flow in Components of Parallel Pipe Systems

CHART FOR DETERMINATION OF EQUIVALENT PIPES

By J. R. ARBUTHNOT
Asst. Engr., Kansas State Dept. of Health, Lawrence, Kan.

THE use of "flow resistance factors" has become widespread in the calculation of the loss of head in pipes and pipe networks, particularly in the Hardy Cross method of analysis. Through the use of flow resistance factors and the accompanying chart, the determination of equivalent pipes can be performed very easily, and in a manner working in very well with the usual beginning of a Hardy Cross analysis.

Explanation

Pipes with the same flow resistance factor will have the same loss of head at the same discharge and are therefore equivalent. Flow resistance factors are obtained by placing any of the common formulas for the flow of water in pipes in the form:

$$h = rQ^n \qquad \text{(Eq. 1)}$$

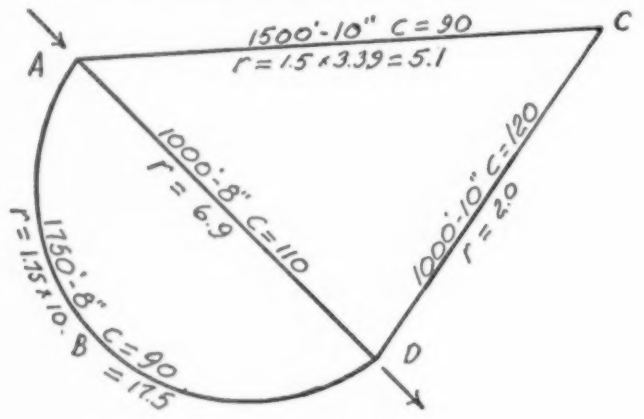
where r is the flow resistance factor, h is the head lost due to a discharge Q, and n a coefficient of the particular formula. In this form the Hazen and Williams formula becomes:

$$h = rQ^{1.85}$$

In the Hazen and Williams formula if the head loss, h, is expressed in feet per 1,000 feet of pipe, the diameter of the pipe, D, in feet, and the discharge, Q, in gallons per minute, then

$$r \times 10^5 = \frac{5796 \quad 9047}{C^{1.852}\, D^{4.87}} \qquad \text{(Eq. 2)}$$

where C is the Hazen and Williams coefficient. From this



Pipe Loop Diagram

expression values of r per 1,000 feet of pipe can be calculated for any size and roughness of pipe. A table of values for the flow resistance factor, computed from Equation 2, is given in Table I. Tables of values of r for Q or h in other units can easily be computed.

It can readily be demonstrated that the r value of a pipe equivalent in carrying capacity to two or more other parallel pipes has the relationship to the r values of other pipes shown in the following equation:

$$\frac{1}{r^{p_o}} = \frac{1}{r^{p_1}} + \frac{1}{r^{p_2}} + \ldots\ldots \frac{1}{r^{p_n}} \qquad \text{(Eq. 3)}$$

In this equation n is the total number of distinct parallel pipe lines including pipes 1 and 2, to which pipe "o" is equivalent, and p is a coefficient whose value depends upon the pipe-flow formula on which Equation (3) is based. The solution of Equation (3), with p given the value of 0.54 from the Hazen and Williams equation, is simplified through use of the accompanying chart. This chart can be used with values of r from Table I for the rapid determination of equivalent pipes. The chart can be used with equal facility in conjunction with any other tables of r, as long as these tables are based upon the Hazen and Williams formula. It will be observed that the position of the decimal point can be switched at will in using the chart, as long as each r value is operated upon by the same power of ten.

TABLE I.

Values of Flow Resistance Factor x 10^5
For 1,000 ft. of Main with Q in gpm.

Pipe C Diam.	80	90	100	110	120	130	140
4 in. ..	365.0	293.4	241.4	202.4	172.2	148.5	129.5
6 in. ..	50.7	40.7	33.5	28.1	23.9	20.6	18.0
8 in. ..	12.5	10.0	8.26	6.92	5.89	5.08	4.43
10 in. ..	4.21	3.39	2.79	2.33	1.99	1.71	1.49
12 in. ..	1.73	1.39	1.15	0.961	0.818	0.705	0.615
14 in. ..	0.818	0.658	0.541	0.453	0.386	0.333	0.290
16 in. ..	0.427	0.343	0.282	0.237	0.201	0.174	0.151
18 in. ..	0.240	0.193	0.159	0.133	0.113	0.0979	0.0853
20 in. ..	0.144	0.116	0.0952	0.0798	0.0679	0.0586	0.0511
24 in. ..	0.0592	0.0476	0.0392	0.0329	0.0280	0.0241	0.0210
30 in. ..	0.0200	0.0161	0.0132	0.0111	0.0094	0.0081	0.0071

Example

The use of the chart will be demonstrated by the determination of a pipe equivalent to the three pipe lines shown in the accompanying diagram. Flow resistance factors were obtained from Table I.

The total flow resistance factor for ACD is of course 5.1 + 2.01 or 7.1. (The factor 10^5 can be dropped here since we will automatically pick it up again when we reenter the table with the r value of our equivalent pipe.) A line drawn on the chart connecting the values of 7.1 and 17.5 indicates that a pipe equivalent to ACD and ABC has a flow resistance factor of about 2.9. Similarly a pipe equivalent to ACD, AD, and ABD, is determined to have a flow resistance factor of 1.2. A length of any pipe with this flow resistance factor will then be equivalent in carrying capacity to the system of pipes shown in the diagram, as for instance $\frac{1.2}{1.15}$ x 1,000, or 1,040 ft. of 12 in. pipe with C of 100; $\frac{1.2}{0.24}$ x 1,000 or 5,000 ft. of 18 in. pipe with C of 80; or, $\frac{1.2}{8.26}$ x 1,000 or 145 ft. of 8 in. pipe with C of 100.

In the solution of problems of this sort the value of the Hazen and Williams coefficient C is usually not accurately known. The diagram will therefore usually furnish figures with all justifiable exactness. The values of the chart are marked off according to the scale equation $x = mu^{0.54}$, where m is the scale modulus, taken as 1.44 inches. If greater accuracy were desired the scale modulus could be taken as 2 or even 3 inches and the scales extended. The axes of the chart intersect at an angle of sixty degrees.

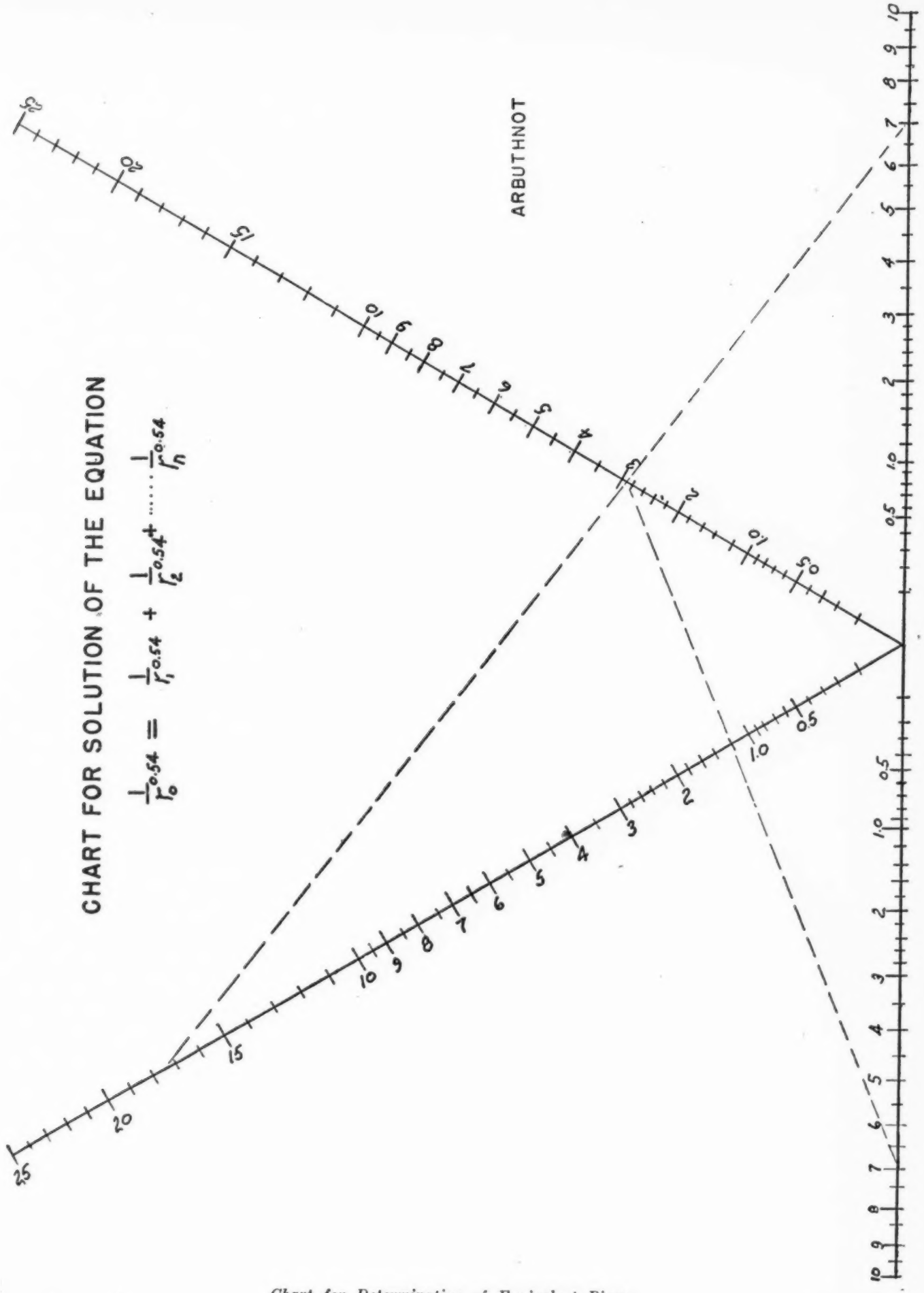
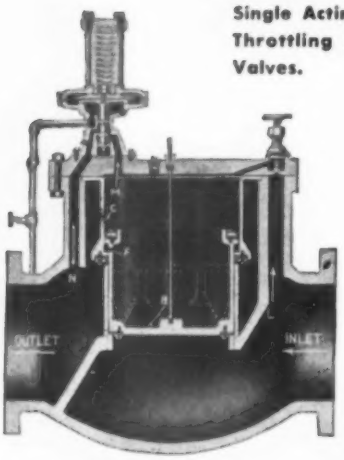


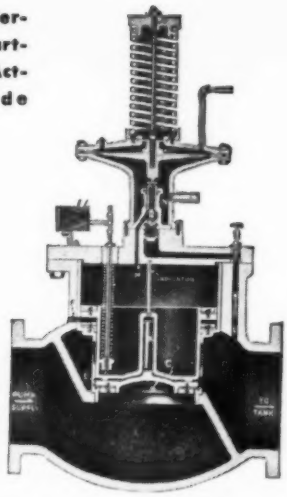
Chart for Determination of Equivalent Pipes

Golden-Anderson Single Acting Semi-Throttling Altitude Valves.



For New Construction or Rehabilitation

Golden-Anderson Stop Starter Single Acting Altitude Valves.

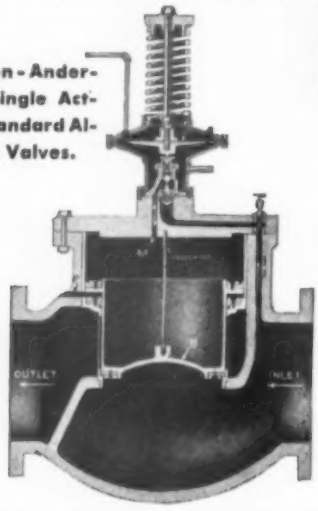


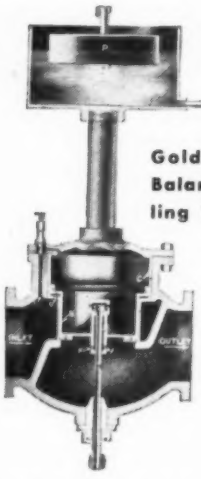
STANDARDIZE ON

GOLDEN-ANDERSON VALVES

for Engineered Protection

Golden-Anderson Single Acting Standard Altitude Valves.





Golden-Anderson Balanced Controlling Float Valves.

A dependable source for your most Important Valve Requirements

Golden-Anderson Altitude Control Valves require no floats or complicated fixtures in their installation. They can be easily installed and protected from inclement weather to assure unfailing water service control under any climatic conditions. Sensitive operation is another outstanding feature—they faithfully maintain water levels within 3" to 12" variation and may be arranged with auxiliary equipment to perform a multiplicity of services. Write for latest technical catalog.

Let Golden-Anderson Engineers aid in your Planning

Our engineers are available to aid in the successful solution of any difficult valve problem.

GA

GOLDEN-ANDERSON VALVE Specialty Company
PITTSBURGH 22, PA.

write for descriptive technical catalog

LOSS OF HEAD IN PIPES AND FITTINGS†

THERE are numerous times when a water works engineer wishes to know the loss in head in some particular line. Information on this subject is not lacking but often is scattered in various texts and magazines. Diagramatic charts, prepared by the application of the Hazen-Williams, and Scobey formulas for flow of water in pipes have been developed as aids to the solution of problems involving loss of head. Tables and charts of loss of head through valves and fittings are likewise available from various sources and authors.

In an attempt to bring these data tables, charts, and diagrams together in one place the following collection is presented. Together with such running comment as is necessary, the information in the following pages should be sufficient to solve any problem in loss of head.

Flow of Water in Pipe**

The carrying capacity of a pipe line may be regarded as the index of its hydraulic efficiency. Selection of the most suitable hydraulic characteristics to satisfy the economics of a given installation usually involves consideration of several alternate procedures, and comparisons of their respective characteristics, before the most appropriate choice can be made. These comparisons can only be as valid as the underlying hydraulic assumptions they depend on, hence the importance of suitable expressions correctly formulating the proper relationships involved.

Many studies have been made to determine these relationships, and many formulae developed to express them. In 1775, Chezy, a French engineer, offered his well-known formula for the flow of water in open channels and closed conduits:

$$V = C\sqrt{r\,s},$$

"C" being a coefficient at first supposed to have a constant value, but now known to vary with the velocity, slope, hydraulic radius, and with some factor representing influences of contact surfaces. The Kutter elaboration of the Chezy formula reads:

$$V = \left\{ \frac{\frac{1.811}{n} + \frac{0.00281}{s} + 41.66}{1 + \frac{n}{\sqrt{r}}\left(41.66 + \frac{0.00281}{s}\right)} \right\} \sqrt{r\,s},$$

in which "C" of the Chezy formula has been developed into the bracketed expression shown at left, which also introduces a new variable "n", supposed to represent all retarding influences. Unfortunately, however, the value of "n" varies somewhat for pipe, both with size and velocity. Now if we examine for a moment the basic formula

$$h_f = \frac{f\,L\,V^2}{2gd}$$

which can be established by the usual hydraulic reasoning, we find the Chezy formula recognizable in it, and also the well-known formula of Darcy, Weisbach and Fanning. All these suffer in a basic respect, in that the friction "constant" does not remain constant throughout the range of application. In the early 1900's these discrepancies began to create a definite reaction against the use of the basic simple assumption that $V = C\sqrt{r\,s}$*, culminating in the presentation of the Williams-Hazen formula. In other words, more critical scrutiny and application of available data indicated that the loss of head does not vary as the square of the velocity, but in accordance with a value lying somewhere between 1.70 and 2.00. It is now fairly well understood that theirs (i. e., the exponential type of formula) is preferable to any other form; also that losses within most closed conduits at velocities within the range of ordinary extremes of service require what Scobey calls "a compromise value somewhat less than 2.00".

The Williams-Hazen formula is now widely accepted, and reads:

$V = C\,r^{0.63}\,s^{0.54}\,.001^{-0.04}$, where

V = mean velocity of flow, in feet per second.
C = "coefficient of retardation," so-called.
r = mean hydraulic radius of the pipe, or diameter D ÷ 4, in feet.
s = hydraulic grade or slope, in feet per foot of length of a pipe of uniform size.

or

$$s^{0.54} = \frac{V}{C\left(\frac{D}{4}\right)^{0.63}\,.001^{-0.04}} = \frac{4^{0.63}\,V}{1.318\,C\,D^{0.63}}$$

$$s = \frac{4^{1.167}\,V^{1.852}}{1.318^{1.852}\,C^{1.852}\,D^{1.167}} = \frac{3.0236\,V^{1.852}}{C^{1.852}\,D^{1.167}}$$

$$S_{1000}\left\{\begin{matrix}\text{Loss of Head}\\ \text{in Feet, per}\\ \text{1,000 Feet}\end{matrix}\right\} = \frac{3023.6\,V^{1.852}}{C^{1.852}\,D^{1.167}} = K\frac{V^{1.852}}{D^{1.167}}$$

when $\left\{\begin{matrix}C = & 90 & 95 & 100 & 105 & 110 & 115 & 120 & 125 & 130 & 135 & 140\\ K = & .727 & .657 & .598 & .546 & .501 & .461 & .426 & .395 & .367 & .343 & .321\end{matrix}\right\}$

Loss of Head Charts Based on the Hazen-Williams and Scobey Formulas

In the following pages appear four charts for determining loss of head in lineal pipe lines. The first three were developed from the Hazen-Williams Formula and apply to any pipe. The last was developed from the Scobey formula and is applicable to concrete pipes.

The first of these charts was prepared by William P. Creager, Chief Engineer, The Power Corporation of New York, and was originally published by John Wiley and Sons in Hydro-Electric Handbook, by Creager and Justin.

The second and third of these charts are nomographs and were prepared for an article on the Hardy Cross Method by D. R. Taylor (WATER WORKS AND SEWERAGE, March 1943). The last chart, also a nomograph, was prepared by J. R. Griffiths, of the U. S. Navy, and first appeared in *Western Construction News*.

Values of the Coefficient "C"

Although the second and third charts are for definite values of the friction coefficient "C" in the Hazen-Williams Formula, the first chart by Creager may be used for any value of "C," if that value is known.

Recommended values of "C" for the Hazen-Williams Formula were given by Hazen and Williams in their book, "Hydraulic Tables" published by John Wiley and Sons, in 1920. These values for straight line conduits are shown in the following tables.

TABLE I—TABLE OF C VALUES
CAST IRON PIPE

Diameter Inches	Age in Years*						
	0	5	10	20	30	40	50
4	130	118	107	89	75	64	55
8	130	119	109	93	83	73	65
12	130	120	111	96	86	77	70
16	130	120	112	98	87	80	72
24	130	120	113	100	89	81	74
30	130	120	113	100	90	83	76
36	130	120	113	100	90	83	76
40	130	120	113	100	90	83	77
60	130	120	113	100	90	83	77

*Cleaning old pipe increases the C value.

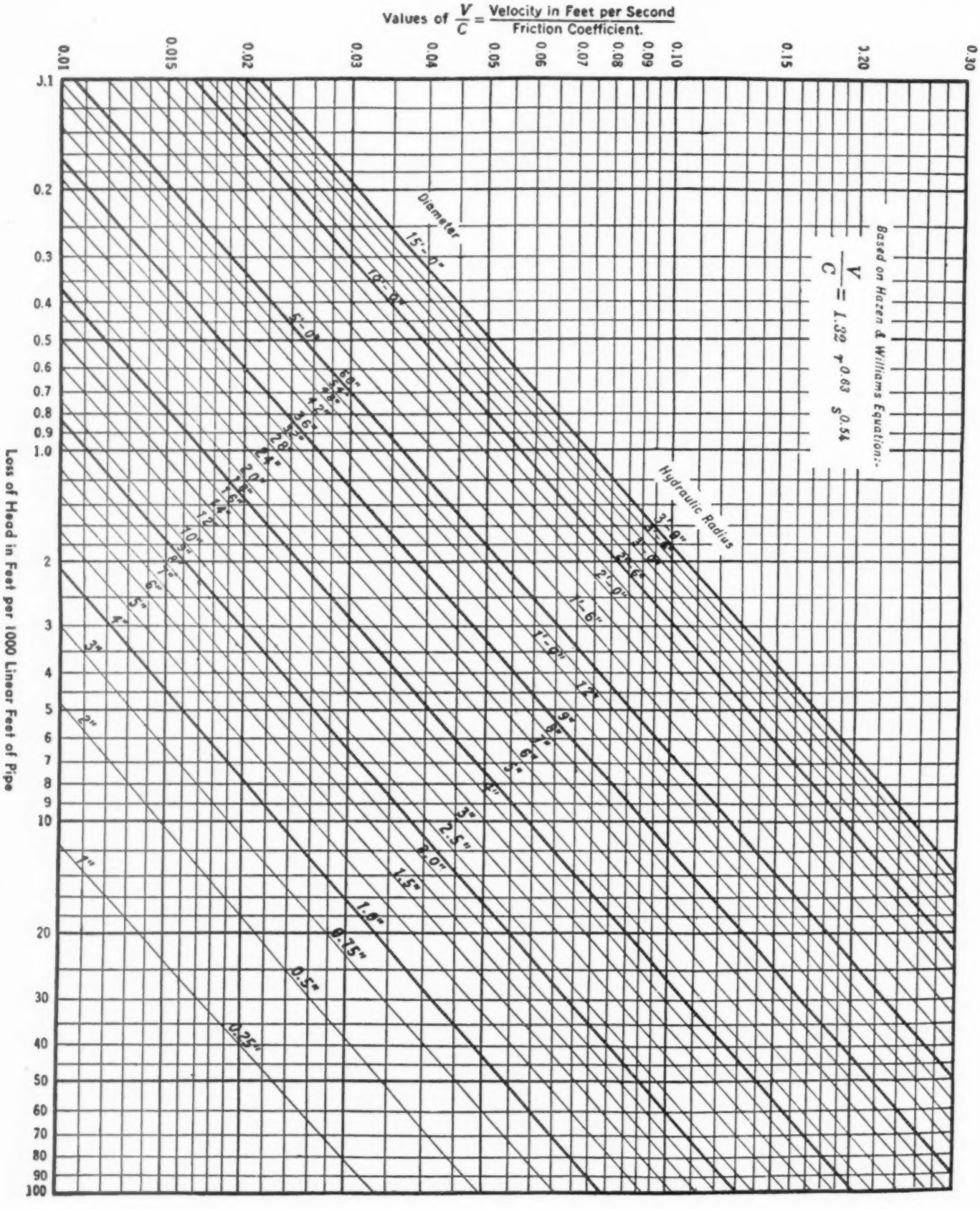
Riveted Steel Pipe
  Light riveted steel pipe—Avg. C for any age = 10 year C.I.P.
  Heavy riveted steel pipe—Avg. C for any age = 20 year C.I.P.
Welded Steel Pipe
  Equivalent to 5 yr. or older C.I.P.
Wood Stave Pipe
  Best C = 145
  Probable Average C = 120
  Worst C = 110
Concrete Pipes and Pressure Tunnels
  Metal Forms
    Best workmanship— C = 150
    Probable workmanship—C = 140
    Worst workmanship— C = 120
  Wood Form—Monolithic
    Best workmanship— C = 130
    Probable workmanship—C = 120
    Worst workmanship— C = 90
  If Slimed
    20 points below Best
    15 points below Average
    10 points below Worst

†Prepared from material gathered from the various sources credited in the text.

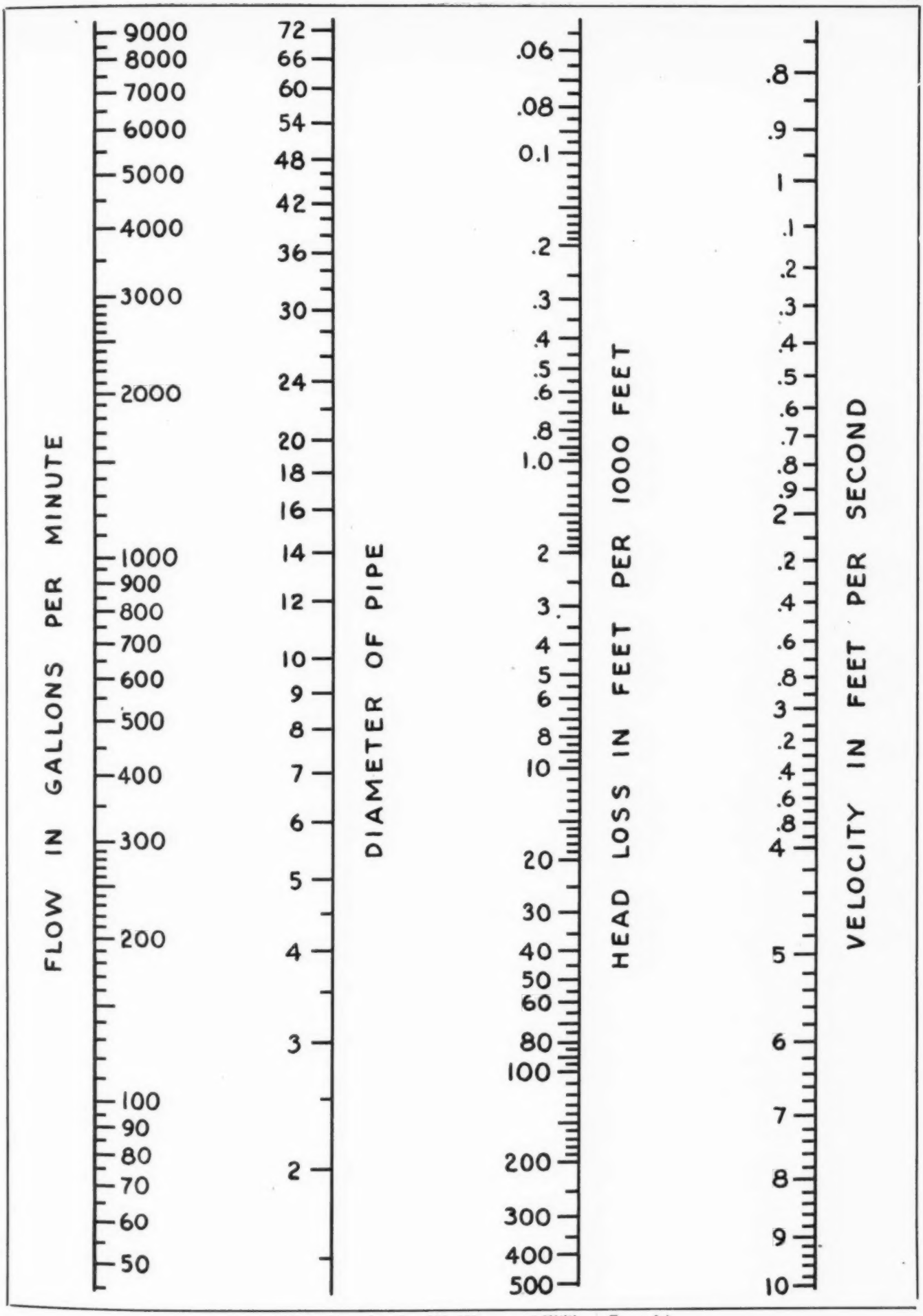
*Convertible into the general formula $H = k\frac{Vx}{D^y}$; when H = 1000s, x = 2, and y = 1.

**From Cat. No. 404, Taylor Forge and Pipe Works.

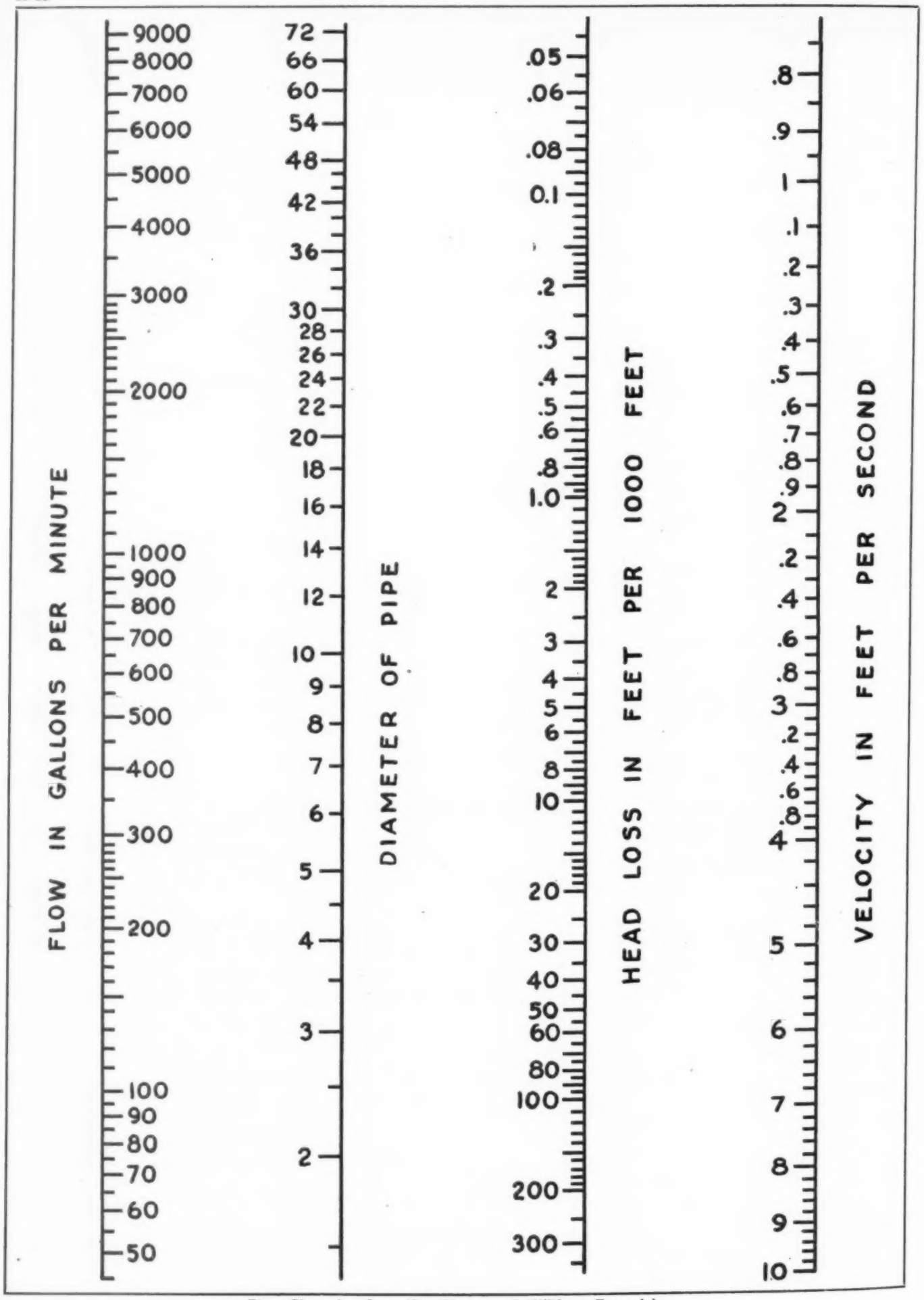
CHART OF LOSS OF HEAD IN FEET PER 1000 FT. OF PIPE



From "Hydro-Electric Handbook"—John Wiley & Sons

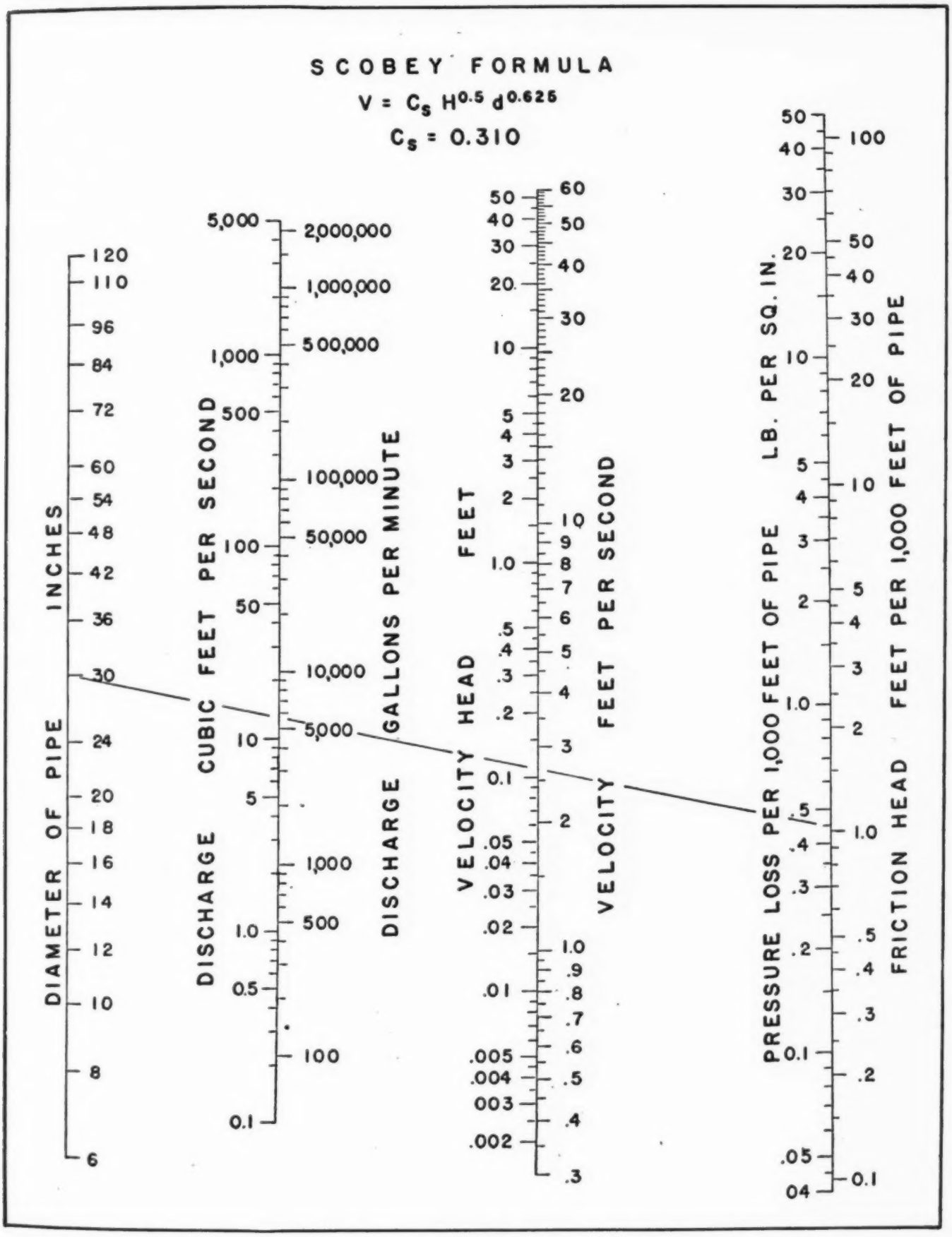


Flow Chart for C = 100 (Hazen and Williams Formula)



Flow Chart for C = 120 (Hazen and Williams Formula)

FLOW OF WATER IN CONCRETE PIPE


SCOBEY FORMULA
V = Cs H0.5 d0.625
Cs = 0.310
DIAMETER OF PIPE INCHES
DISCHARGE CUBIC FEET PER SECOND
DISCHARGE GALLONS PER MINUTE
VELOCITY HEAD FEET
VELOCITY FEET PER SECOND
PRESSURE LOSS PER 1,000 FEET OF PIPE LB. PER SQ. IN.
FRICTION HEAD FEET PER 1,000 FEET OF PIPE

Courtesy of J. R. Griffith, U. S. Navy, and Western Construction News.

In addition to the values in the above table the following values of the friction coefficient have been published by the National Tube Company in Technical Bulletin No. 21.

These values of the coefficient "C" are to be used in the Hazen-Williams formula for computing the loss of head due to friction in new well-laid pipe:

Kind of Pipe	Coefficient	Kind of Pipe	Coefficient
"Duroline"	148*†	Wood Stave	120
Wrought Steel	140	Riveted Steel	110
Small Brass and Copper	130	Vitrified Pipe	110
Cast Iron	130	Brick Sewers	100
Concrete	120		

*"Duroline" pipe is protected against internal corrosion and mounting friction losses by a cement base composition lining of a highly durable nature.—Ed.
†Approximately the same for cement lined pipe.—Ed.

It must be understood that these values depend upon the smoothness and regularity of the surfaces and are likely to vary in individual cases. In designing a pipe line it is customary to use somewhat lower coefficients than those above, to allow for variations due to local conditions, and for reduction of carrying capacity with age due to roughening of the inside surface, accumulation of corrosion products, and tuberculation. However, in case of cement or enamel lined pipe, the volume of flow remains practically unchanged over long periods of service due to the fact that rust tubercles do not form and the initially smooth inside surface is retained.

Useful Loss of Head Tables

D. R. Taylor in his article in Water Works and Sewerage (Mar. 1943) gives two tables on loss of head. The first (table II) gives values for use in the formula

$$S = r\,Q_m^{1.85}$$

where S = loss of head per 1000 ft.
r = resistance factor depending on size and smoothness of pipe.
Q_m = quantity of flow in gal. per min.

Values in the table are given as "k" values which are equal to 100,000 times the "r" value.

TABLE II

Values of k for 1,000 Feet of Pipe Based on the Hazen-Williams Formula

Pipe Diameter, Inches	C = 90	100	110	120	130	140
4	300	248	208	117	153	133
6	41	33.7	28.4	24.2	20.9	18.2
8	10	8.4	7.0	6.0	5.2	4.5
10	3.4	2.8	2.4	2.0	1.7	1.5
12	1.5	1.2	1.0	.83	.71	.62
14	.66	.55	.46	.39	.34	.30
16	.35	.29	.24	.20	.18	.15
18	.20	.16	.14	.12	.10	.09
20	.12	.10	.08	.07	.06	.05
24	.049	.04	.03	.03	.02	.02
30	.016	.013	.011	.010	.008	.007
36	.0067	.0054	.0046	.0039	.0034	.0030

Table III gives "r" values when the flow quantity is expressed in mil. gal. per day, for the formula $S = rQ_x^{1.85}$
where s = loss of head per 1000 ft. of pipe.
r = resistance factor
Q_x = quantity flow in m.g.d.

In Table IV are listed pipe friction for various size pipes and velocities. This table is taken from a Layne-Bowler Pump Bulletin.

Loss of Head for Valves and Fittings

The following discussion and its accompanying chart titled Friction Chart for Valves and Fittings have been taken from Crane Company's "Engineering Data on Flow of Fluids in Pipes --Tech. Bull. No. 405, 1935."

When the flow of a fluid in a pipe line is altered by some obstruction such as a valve or fitting, the velocity is changed, turbulence is magnified and a drop in pressure results. This pressure drop may be insignificant in long lines where it is very small in comparison to the total drop, but when the line is short the pressure drop through valves and fittings becomes a major item in the total pressure drop value.

The most widely used data on the subject of the resistance of valves and fittings to the flow of water and steam is the information given in Dean Foster's paper on "Effect of Fittings on Flow of Fluids Through Pipe Lines" published in Vol. 42, 1920, of the Transactions of the American Society of Mechanical Engineers. Recently, tests conducted by others have indicated that the values given by Foster are low for globe valves, angle valves, etc., and that data is needed to establish the correct information to use. It has been the tendency, and probably is the most practical way, to present the friction values in terms of an equivalent length of the same size of pipe; i.e., the pressure drop caused by a 2-inch elbow is equivalent to approximately the pressure drop caused by five or six feet of 2-inch pipe under the same conditions of flow.

Realizing the need for definite data covering this subject, Crane Co. has recently conducted pressure drop tests on valves and fittings on both water and steam. These tests were made on 2 inch and 6 inch sizes and conducted under conditions which were thoroughly investigated previous to the tests. The results of these tests are presented herewith together with a description of the method used in conducting them.

[*Note.*—Water and steam can be treated comparatively and a relation can be established between the relative friction values of water and steam. Foster has stated that the equivalent length of pipe for steam flow is about .8 of that established for the flow of water.]

Friction Losses of Water Line Valves and Fittings

The tests for determining the pressure drop of valves and fittings installed in a water line were made in the following manner:

A flow nozzle was installed in a 3 in. test line leading from the bottom of a 1,000 gallon water tank. A mercury manometer was set across this nozzle and the relation of mercury deflection to the gallons of water per minute flowing through the pipe was determined. The flow through the pipe was thereafter noted only in terms of mercury deflection which was readily transposed into gallons per minute by reference to the calibration chart.

The valve or fitting to be tested was placed in the line at some distance from the flow nozzle and the flow water through it was regulated by a throttling valve situated at the outlet of the line. The pressure drop was measured by means of a mercury manometer, or where the deflection was too great, by two sensitive low pressure gages, the leads of which were situated in the test line at a distance of ten pipe diameters (20 in.)

TABLE III

VALUES OF "R" FOR 1,000 FT. OF PIPE BASED ON HAZEN AND WILLIAMS FORMULA

Head Loss in Ft.: $S = r \times Q^{1.85}$ per 1,000 ft. (Q in M.G.D.)

d—Inches	c = 70	c = 80	c = 90	c = 100	c = 110	c = 120	c = 130	c = 140
4	860.69	672.31	540.67	444.91	373.00	317.53	273.83	238.76
6	119.44	93.30	75.03	61.74	51.76	44.06	38.00	33.13
8	29.42	22.98	18.48	15.21	12.75	10.85	9.36	8.16
10	9.93	7.75	6.24	5.13	4.30	3.66	3.16	2.75
12	4.08	3.19	2.57	2.11	1.77	1.51	1.30	1.13
14	1.925	1.504	1.209	0.995	0.834	0.710	0.612	0.534
16	1.007	0.787	0.633	0.521	0.437	0.372	0.320	0.279
18	0.567	0.443	0.356	0.293	0.246	0.209	0.180	0.157
20	0.3390	0.2648	0.2130	0.1753	0.1469	0.1251	0.1079	0.0941
24	0.1396	0.1091	0.0877	0.0722	0.0605	0.0515	0.0444	0.0378
30	0.0471	0.0368	0.0296	0.0244	0.0204	0.0174	0.0150	0.0151
36	0.01939	0.01514	0.01218	0.01002	0.00840	0.00715	0.00617	0.00528
42	0.00915	0.00715	0.00575	0.00473	0.00397	0.00338	0.00291	0.00254
48	0.004774	0.003729	0.002999	0.002468	0.002057	0.001761	0.001519	0.001324
60	0.001611	0.001258	0.001012	0.000833	0.000698	0.000594	0.000513	0.000447
66	0.001013	0.000791	0.000636	0.000524	0.000439	0.000374	0.000322	0.000281

TABLE IV

Friction of Water in Pipes

The pipe frictions shown in the following tables are taken by permission from the more complete copyright tables by Williams and Hazen, published by John Wiley & Sons, and these values are recommended for use in figuring pipe frictions.

Loss of Head in Feet Due to Friction, per 100 feet of 15 year old Ordinary Iron Pipe

U.S. Gal's per Min.	1" Pipe		1¼" Pipe		1½" Pipe		2" Pipe		2½" Pipe		3" Pipe	
	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.
10	3.72	11.7	2.14	3.05	1.57	1.43	1.02	0.50	0.65	0.17	0.45	0.07
15	5.60	25.0	3.2	6.50	2.36	3.0	1.53	1.0	0.98	0.36	0.68	0.15
20	7.44	42.0	4.29	11.1	3.15	5.2	2.04	1.82	1.31	0.61	0.91	0.25
25	9.30	64.0	5.36	16.6	3.94	7.8	2.55	2.73	1.63	0.92	1.13	0.38
30	11.15	89.0	6.43	23.5	4.72	11.0	3.06	3.84	1.96	1.29	1.36	0.54
35	13.02	119.0	7.51	31.2	5.51	14.7	3.57	5.1	2.29	1.72	1.59	0.71
40	14.88	152.0	8.58	40.0	6.3	18.8	4.08	6.6	2.61	2.20	1.82	0.91
45			9.65	50	7.08	23.2	4.60	8.2	2.94	2.80	2.05	1.15
50			10.72	60	7.87	28.4	5.11	9.9	3.27	3.32	2.27	1.38
70			15.01	113	11.02	53.0	7.15	18.4	4.58	6.2	3.18	2.57
90					14.17	84.0	9.19	29.4	5.88	9.8	4.09	4.08
100					15.74	102.0	10.21	35.8	6.54	12.0	4.54	4.96
120					18.89	143.0	12.25	50.0	7.84	16.8	5.45	7.0
140					22.04	190.0	14.30	67.0	9.15	22.3	6.35	9.2
160							16.34	86.0	10.46	29.0	7.26	11.8
180							18.38	107.0	11.76	35.7	8.17	14.8
200							20.42	129.0	13.07	43.1	9.08	17.8
220							22.47	154.0	14.38	52.0	9.99	21.3
240							24.51	182.0	15.69	61.0	10.89	25.1
260							26.55	211.0	16.99	70.0	11.80	29.1
280									18.30	81.0	12.71	33.4
300									19.61	92.0	13.62	38.0

U. S. Gal's per Min.	4" Pipe		5" Pipe		6" Pipe		8" Pipe		10" Pipe		12" Pipe		14" Pipe		15" Pipe		16" Pipe		20" Pipe		24" Pipe	
	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.
40	1.02	0.22																				
45	1.17	0.28																				
50	1.28	0.34																				
70	1.79	0.63	1.14	0.21																		
75	1.92	0.73	1.22	0.24																		
100	2.55	1.22	1.63	0.41	1.14	0.14																
120	3.06	1.71	1.96	0.58	1.42	0.25																
125	3.19	1.86	2.04	0.64	1.48	0.28																
150	3.84	2.55	2.45	0.88	1.71	0.32																
175	4.45	3.44	2.86	1.18	2.00	0.48																
200	5.11	4.40	3.27	1.48	2.28	0.62																
225	5.77	5.45	3.67	1.86	2.57	0.74																
250	6.40	6.72	4.08	2.24	2.80	0.92	1.60	0.22														
270	6.90	7.70	4.42	2.60	3.03	1.13	1.70	0.25														
275	7.03	7.99	4.50	2.72	3.06	1.15	1.73	0.27														
300	7.66	9.30	4.90	3.14	3.40	1.29	1.90	0.32														
350	8.90	12.32	5.72	4.19	3.98	1.75	2.20	0.42														
400	10.21	16.00	6.54	5.40	4.54	2.21	2.60	0.54														
450	11.50	19.80	7.35	6.70	5.12	2.65	2.92	0.68	1.80	0.21												
470	12.10	22.40	7.70	7.22	5.49	2.90	3.07	0.75	1.92	0.24												
475	12.20	22.96	7.76	7.42	5.55	2.95	3.10	0.76	1.94	0.25												
500	12.77	24.00	8.17	8.12	5.60	3.30	3.20	0.82	2.04	0.28	1.42	0.11										
550			8.99	9.60	6.16	3.93	3.52	0.97	2.25	0.33	1.57	0.14										
600			9.80	11.30	6.72	4.70	3.84	1.14	2.46	0.39	1.71	0.15										
650			10.62	13.20	7.28	5.40	4.16	1.34	2.66	0.46	1.85	0.19	1.37	0.09								
700			11.44	15.10	7.84	6.20	4.46	1.54	2.86	0.52	2.00	0.22	1.47	0.10								
750			12.26	17.20	8.50	7.00	4.80	1.74	3.06	0.59	2.13	0.24	1.58	0.11								
800					9.08	8.00	5.12	1.97	3.28	0.67	2.27	0.27	1.68	0.13								
850					9.58	8.95	5.48	2.28	3.48	0.75	2.41	0.31	1.79	0.14								
900					10.30	10.11	5.75	2.46	3.68	0.83	2.56	0.34	1.89	0.16								
950					10.72	10.80	6.06	2.87	3.88	0.91	2.70	0.38	2.00	0.18	1.73	0.12						
1000					11.32	12.04	6.40	3.02	4.08	1.01	2.84	0.41	2.10	0.19	1.82	0.14						
1050					11.90	13.30	6.70	3.21	4.29	1.09	2.98	0.44	2.20	0.22	1.91	0.16						
1100					12.50	14.31	7.03	3.51	4.50	1.20	3.13	0.49	2.31	0.23	2.00	0.17						
1150					12.95	15.60	7.35	3.84	4.71	1.34	3.27	0.53	2.42	0.25	2.09	0.18						
1200					13.52	16.69	7.67	4.15	4.91	1.46	3.41	0.57	2.52	0.26	2.18	0.19						
1250					14.10	18.50	8.00	4.45	5.11	1.51	3.55	0.62	2.63	0.29	2.28	0.20	1.99	0.15				
1500							9.60	6.27	6.10	2.09	4.20	0.85	3.15	0.39	2.73	0.28	2.39	0.21				
2000							12.70	10.71	8.10	3.65	5.60	1.43	4.20	0.66	3.64	0.54	3.19	0.39			1.42	0.05
2500									10.10	5.33	7.00	2.28	5.25	1.01	4.55	0.72	3.99	0.56			1.77	0.07
3000									12.10	7.80	8.40	3.15	6.30	1.47	5.46	1.12	4.79	0.80	3.08	0.27	2.13	0.10
3500									14.10	10.08	9.80	4.10	7.35	1.81	6.37	1.43	5.59	1.04	3.59	0.35	2.49	0.14
4000											11.35	5.32	8.40	2.47	7.28	1.85	6.38	1.34	4.10	0.45	2.85	0.18
4200											11.93	6.00	8.82	2.80	7.64	2.08	6.72	1.45	4.32	0.50		
4500											12.78	6.90	9.45	3.22	8.19	2.23	7.20	1.65	4.62	0.56	3.20	0.22
5000											14.20	8.40	10.50	3.92	9.10	2.78	7.96	2.02	5.13	0.68	3.54	0.27
5500													11.55	4.65	10.01	3.30	8.78	2.39	5.64	0.82	3.90	0.33
6000													12.60	5.50	10.92	3.90	9.56	2.60	6.15	0.96	4.25	0.38
6500													13.65	6.45	11.83	4.55	10.36	3.32	6.66	1.06	4.61	0.45
7000													14.70	7.15	12.74	5.08	11.12	3.68	7.18	1.28	4.97	0.52
7200															13.10	5.45	11.50	3.96	7.38	1.35		
7500															13.65	5.90	11.95	4.28	7.66	1.45	5.32	0.59
8000																			8.17	1.63	5.68	0.66
8500																			8.68	1.83	6.03	0.74
9000																			9.20	2.04	6.35	0.81
9500																			9.70	2.23	6.74	0.91
10000																			10.40	2.53	7.07	0.98

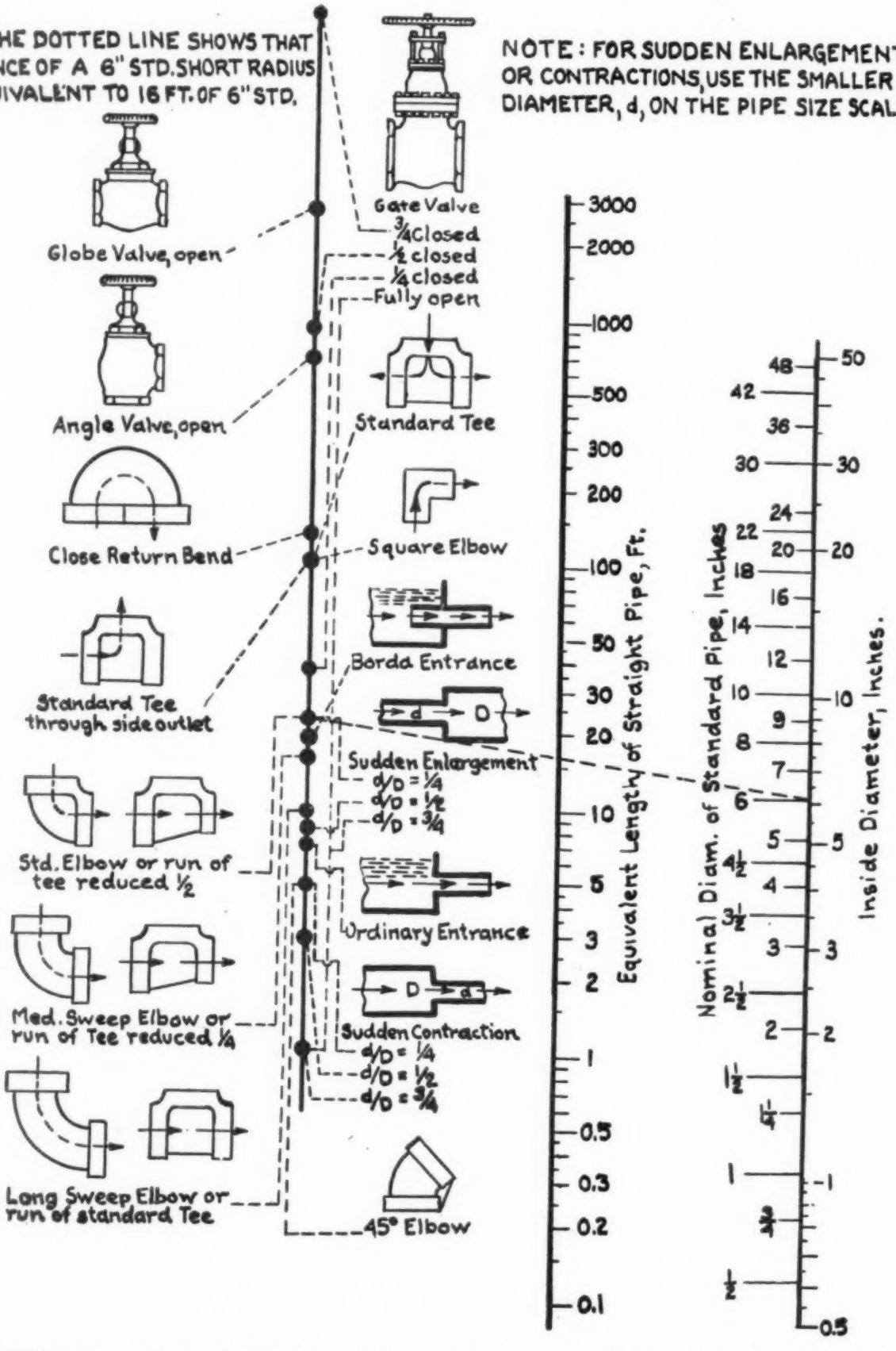
Vel.—Velocity ft. per second. Fric.—Friction head in feet.

FRICTION CHART FOR VALVES AND FITTINGS

For Converting These Units Into Equivalent Added Length of Pipe*

EXAMPLE: THE DOTTED LINE SHOWS THAT THE RESISTANCE OF A 6" STD. SHORT RADIUS ELBOW IS EQUIVALENT TO 16 FT. OF 6" STD. PIPE.

NOTE: FOR SUDDEN ENLARGEMENTS OR CONTRACTIONS, USE THE SMALLER DIAMETER, d, ON THE PIPE SIZE SCALE.



*Note: These equivalents, in terms of length of pipe to be added in computations, were derived for steel pipe in good condition. In applying the chart to cast-iron pipe divide the equivalent length of steel pipe by 1.64 times the most appropriate age factor found in the accompanying table of "Age Factors" for C.I. mains.

from each end of the valve or fitting on test. The initial pressure at the inlet of the test line was kept constant at 80 pounds per square inch and the various rates of flow produced by throttling the outlet of the test line.

After the data was obtained the means of presenting it in its best form was investigated. In any pressure drop tabulation, the values for the fittings and valves in the line are added to the pressure drop of the entire length of line. Therefore, it seemed reasonable to disregard the pressure drop caused by the length of the valve or fitting and just list the pressure drop which was added to the line due to the presence of the article.

For instance, if a valve 4 in. face to face is installed in a line 30 in. long, the actual pressure drop through the valve will be the total pressure drop minus the pressure drop caused by 26 in. of pipe. However, in a practical problem this value will be added to the pressure drop caused by the total length of the line which will give a pressure drop value slightly higher than the actual. This may not be so noticeable with one or two valves or fittings in the line, but where the number runs up into 10 or 20 the added drop may be considerable.

This "No-length" concept was established and has been used before with reference to elbows in "The Friction of Water in Pipes and Fittings" by F. E. Giesecke, University of Texas Bulletin No. 1759.

Resistance in Terms of Equivalent Pipe Length

From data given in the tests conducted by Crane Co. and also from information gathered from authentic sources, Fig. 16, has been prepared which gives the equivalent length of pipe to produce the same pressure drop as a valve or fitting. This additional pipe length should be added to the length of the line in order to determine the total pressure drop.

The equivalent length of pipe has been based upon the pressure drop values for the flow of water in pipes and upon the following coefficients of

$$H_1 = k\frac{V^2}{2g}$$

H_1 = Loss of head in ft.
k = Coefficient.
V = Vel. in ft. per sec.
$2g$ = 64.4.

Type	Coefficient	Authority
Globe Valves	10	Crane Tests
Angle Valve	5	Crane Tests
Return Bend	2.2	
Tee	1.8	Giesecke & Bladgett—Texas College
Short Radius Elbow.	.9	Giesecke & Bladgett—Texas College
Med. Radius Elbow..	.75	& Crane tests
Long Radius Elbow..	.60	Bulletin No. 2712—U. of Texas
Gate Valve (Open)..	.19	Bulletin No. 252—U. of Wis. (Av.)
¼ Closed	1.15	Bulletin No. 252—U. of Wis. (Av.)
½ Closed	5.6	Bulletin No. 252—U. of Wis. (Av.)
¾ closed	24.0	Bulletin No. 252—U. of Wis. (Av.)
Borda Entrance	.83	"Hydraulic" Daugherty (Average)
Sudden Enlargement		
d/D — ¼	.92	"Hydraulics" Daugherty
d/D — ½	.56	"Hydraulics" Daugherty
d/D — ¾	.19	"Hydraulics" Daugherty
Ordinary Entrance	.5	"Hydraulics" Daugherty
Sudden Contraction		
d/D = ¼	.42	"Hydraulics" Daugherty
d/D = ½	.33	"Hydraulics" Daugherty
d/D = ¾	.19	"Hydraulics" Daugherty
45° Elbow	.42	Bulletin No. 2712—U. of Texas

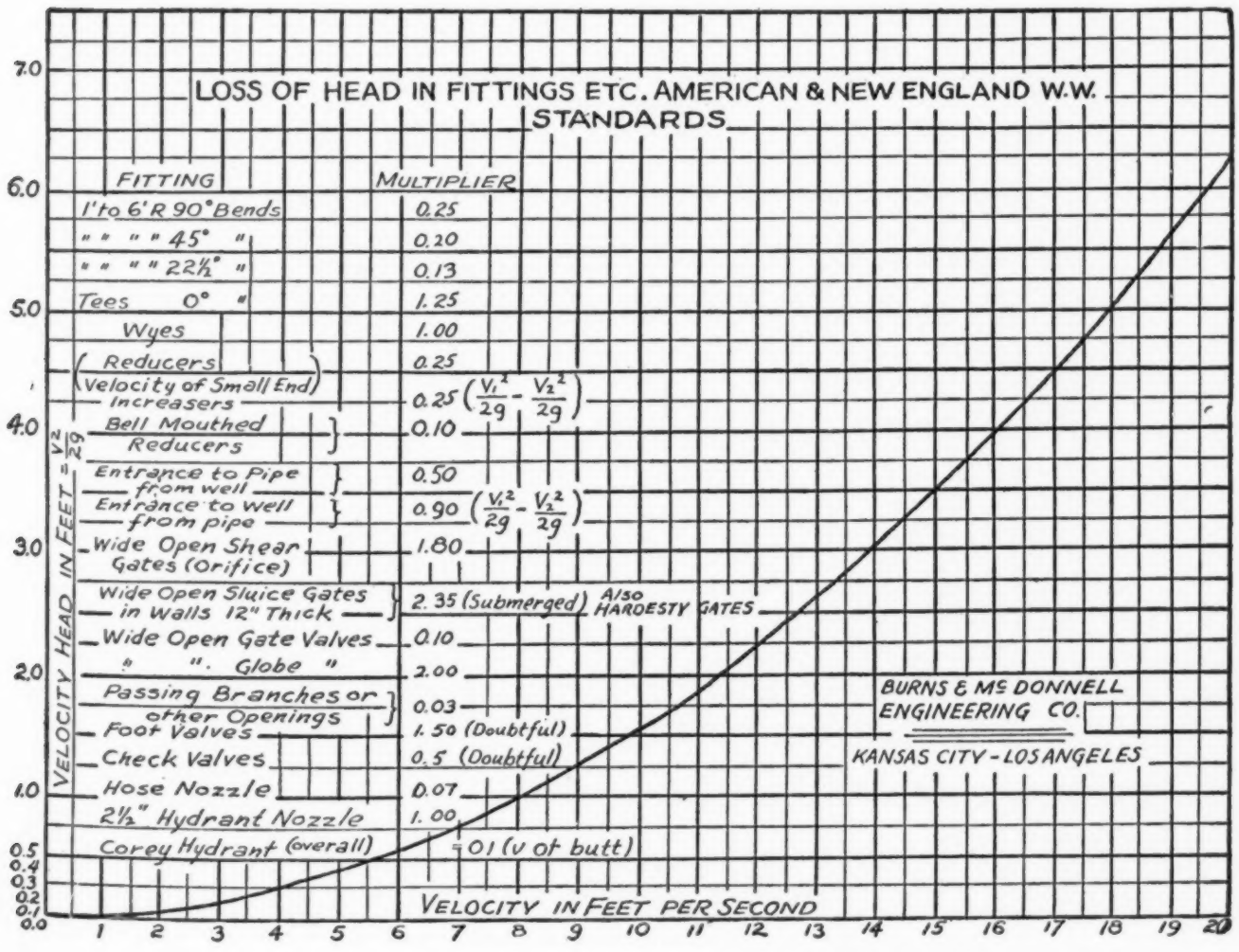
AGE FACTORS

	Age in Years						
	New	10	15	20	30	50	75
Fire Protection Mains							
No Domestic Draft	0.7	0.9	1.0	1.1	1.4	1.8	2.3
Public and Fire Protection Mains with Domestic Draft							
Surface Water							
Slight Tuberculation	0.7	0.9	1.0	1.1	1.4	1.8	2.3
Moderate Tuberculation	0.7	1.2	1.7	2.1	2.9	3.5	3.9
Severe Tuberculation	0.7	1.6	2.4	3.1	4.5	5.2	5.5
Well Water	0.7	1.6	2.4	3.1	4.5	5.2	5.5

These age factors for cast-iron mains are adapted from the results of an investigation by a committee of the New England Water Works Association and reported in their Proceedings, Vol. XLIX, No. 3, September, 1935.

Burns and McDonnell, Engineers, have prepared the following chart to determine loss of head through valves and fittings.

To determine loss of head—Assume flow (Q) to be 5 cu. ft. sec. through a fitting of 12 inch diameter. From Q—AV the


LOSS OF HEAD IN FITTINGS ETC. AMERICAN & NEW ENGLAND W.W. STANDARDS
FITTING
MULTIPLIER
1' to 6' R 90° Bends 0.25
" " " " 45° " 0.20
" " " " 22½° " 0.13
Tees 0° " 1.25
Wyes 1.00
Reducers 0.25
Velocity of Small End Increasers 0.25 (V1²/2g - V2²/2g)
Bell Mouthed Reducers 0.10
Entrance to Pipe from well 0.50
Entrance to well from pipe 0.90 (V1²/2g - V2²/2g)
Wide Open Shear Gates (Orifice) 1.80
Wide Open Sluice Gates in Walls 12" Thick 2.35 (Submerged) Also HARDESTY GATES
Wide Open Gate Valves 0.10
" " Globe " 2.00
Passing Branches or other Openings 0.03
Foot Valves 1.50 (Doubtful)
Check Valves 0.5 (Doubtful)
Hose Nozzle 0.07
2½" Hydrant Nozzle 1.00
Corey Hydrant (overall) .01 (v of butt)
VELOCITY HEAD IN FEET = V²/2g
VELOCITY IN FEET PER SECOND
BURNS & McDONNELL ENGINEERING CO.
KANSAS CITY - LOS ANGELES

velocity (V) = 6.4 ft. per sec. From the chart, velocity head $\frac{V^2}{2g}$ = 0.7 ft. Applied to 90 degree bend head loss is 0.25 × 0.7 = 0.18 ft. For a tee 1.25 × .7 = 0.87 ft.

(Note—Recent correspondence with the producers of this chart cites values for check valves far in excess of the 0.5 indicated.—*Ed.*)

Another method of determining loss of head in fittings and valves is given in the following table with approximate head losses for various fittings. Exact losses cannot be determined due to variation in construction details.

TABLE OF VALUES

Diameter of fittings	1	1½	2	2½	3	4	5	6	7	Inches
Constant	2.5	3.75	5	6.25	7.5	10	12.5	15	17.5	Constant
	8	9	10	11	12	15	16	18	20	Inches
	20	22.5	25	27.5	30	37.5	40	45	50	Constant

MULTIPLIERS FOR DIFFERENT FITTINGS

45° Ell	0.26	Water Meters:	
90° Ell	1.0	Disk or wobble plate type	9.0
Tee	2.0	Rotary (disk of star shape, as piston)	13.3
*Gate Valve	0.37	Reciprocating piston	20.0
*Globe Valve	3.33	Turbine wheel type (Double flow balanced)	8.3
*Angle Globe Valve	5.0	Venturi Meters:	
*Check Valve	3.0	Ratio of $d_2/d_1 = 0.5$	2.66
*Multipliers are for valves operating wide open.		Ratio of $d_2/d_1 = 0.4$	5.66

In the TABLE OF VALUES under each size fitting is a constant which, multiplied by the multiplier for each kind of fitting in the pipe line, will give the additional length in feet to be added to the actual length of discharge pipe or pipe line. Take, for example, a 10-inch pipe line 300-feet long with 2-90° ells, 1-gate valve, 1-check valve and a venturi meter having a ratio of $d_2/d_1 = 0.5$. The additional length for head loss in these fittings is made up as follows: 2-90° ells 25-feet each, 1-gate valve 9-feet, 1-check valve 75-feet, 1-venturi meter 66-feet, making a total of 200-feet additional which must be added to the 300-feet actual length, or the equivalent of 500-feet of new 10-inch pipe line upon which the friction head loss must be figured in order to arrive at the total loss in the pipe line and fittings.

PIPE HANDLING SIMPLIFIED

Power Crane-Equipped Truck Makes for Ease and Economy

By D. R. TAYLOR

Plant Superintendent, Water Department, Roanoke, Virginia

THE problem of transportation is one that many of us were confronted with when we began using cast iron pipe 18 feet long. If you have much hauling to do, it will pay you to buy a long wheel-base truck chassis and to have a power crane installed on it and have a platform body built locally to meet your particular needs. Such a truck chassis that we purchased and equipped when we began the use of 18 foot pipe is here pictured. The power crane was obtained from the Baker Equipment Corp., Richmond, Va., who are our nearest agents for the Gar Wood Industries of Detroit.

The truck chassis should have a wheel base of at least 220 inches. The dimensions of our particular piece of equipment are as follows: The length from the back of the cab to the end of the frame is 19 feet. The crane utilizes 3 feet of this space, and our platform body is 17 feet long, allowing the body to project 1 foot beyond the end of the frame. This allows 18 foot pipe to project 1 foot beyond the body with a total overhang of 2 feet beyond the end of the frame. This is permissible and within the bounds of good practice, as recommended by truck manufacturers. For flexibility and economic transportation, I would suggest that you purchase a heavy duty two-ton chassis, with which you can easily haul a load of four tons from your pipe lot to the job in question without abusing the equipment.

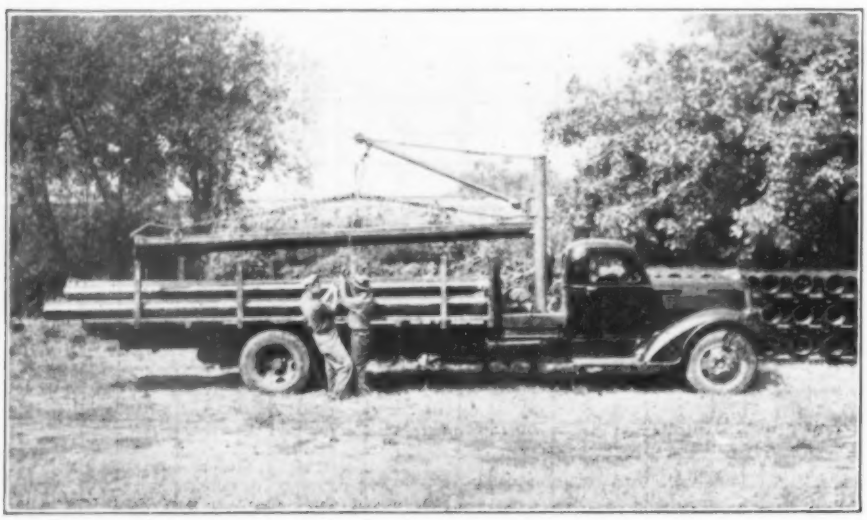
The smaller picture better shows the chain sling with a hook on each end. This was improvised by one of our foremen. The jack, shown in the foreground folded up underneath the crane platform, is one of two furnished with the crane. The jack on the side from which you are raising or lowering the load is unhooked and allowed to swing down to the ground to support the platform while you are loading or unloading.

This crane can be obtained with various capacities and booms of several lengths. I would suggest that you purchase one of 3000 pounds capacity with a 10-foot boom. It may be of interest also to you to learn that the mast and boom is demountable and can be easily removed when not needed.

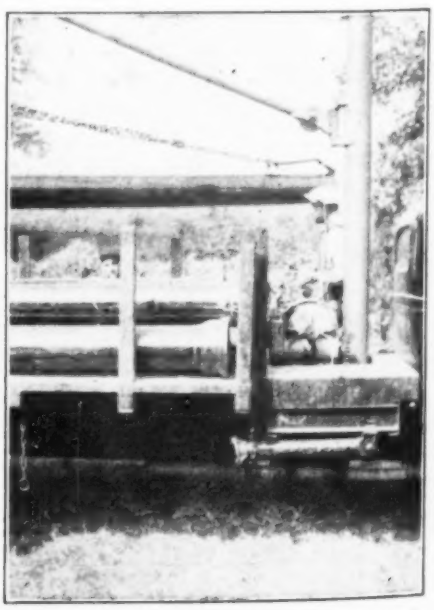
In the good old days, it required six men to unload a car of 8-inch pipe, but, with the outfit described above, three men can do the same job and do it quicker.

If interested in such a purchase and wish any more information, the writer will be glad to give it.

• • •



To Load 18-ft. Lengths of 8-in. Cast Iron Pipe With This Rig Is a Cinch



A Close-Up View Showing Power Crane, the Sling and One of the Support Jacks Beneath the Truck Bed

CHLORINE SOLVES A CRITICAL PROBLEM

Re-establishes Design Capacity of Supply Line

By
L. A. JACKSON and W. A. MAYHAN
Manager *Chemist*
Little Rock Municipal Water Works, Little Rock, Arkansas

IN 1936 construction of a new source of water supply for the City of Little Rock, Ark., was begun. This included the construction of a rolled earthen dam across the Alum Fork River, impounding a lake of 14 billion gallons of water at a point approximately 33 miles west of Litt'e Rock. This distant new source of supply was connected to the Purification Plant, located in Little Rock proper, by the construction of a 39-inch internal diameter, steel-cylinder, reinforced concrete pipe line.

Each pipe section is 16 feet long and weighs 4¼ to 4½ tons. The pipe consists of a welded steel cylinder with galvanized steel joint rings welded to its ends, a concrete lining approximately 1⅛ inches thick, and a concrete covering reinforced with a cage of spirally wound steel rods. The total wall thickness is approximately 4 inches. The joint was of the B&S type with a round rubber gasket, located in a groove on the spigot section.

The spill elevation of Lake Winona, the new source of supply, is 230 feet above the receiving basin elevation at the Filtration Plant in Little Rock, and the flow from the reservoir to the plant is wholly by gravity. At the time of construction no provision was made for sterilizing treatment at the lake end of the line. None was conceived as being justified at the time, for pollution was no problem and subsequent problems had not been foreseen.

New Pipe Line "C" Value of 147

In February, 1938, all construction work was completed.

The lake, having filled to overflowing in December of the preceding year, the new mountain supply was turned into the system. The designed capacity of the 39-inch raw water flow line was 25 mgd. In April, 1938, two months after the pipe line was put into service, it was tested to determine its actual maximum carrying capacity. This test revealed that the line would actually deliver 25.32 mgd., and that Hazen-Williams coefficient "C" for the entire line was 147.

No further tests were made on the line's carrying capacity until a year later (Feb. 23, 1939). A few months before this second test it had been noted that on opening the line wide, it did not deliver 25.32 mgd., but that the capacity was gradually dropping, and at the time of the second test, maximum delivery was only 20.38 mgd. and the average "C" for the entire line was found to have dropped to 120. Thus in the brief period of one year's operation the carrying capacity of the line was reduced 20 per cent. With the fear that we might wake up some morning and not be able to get enough flow through the line for our requirements, something had to be done quickly.

A portion of the line, near the reservoir, was immediately dewatered and inspected. It was found that the interior of the pipe was covered with a very dark, almost black, organic slime deposit or growth, which varied from a very thin film in some places to a heavy mat of more than ¼ inch thickness in others. The growth was rather heavily interspersed with iron oxide and appeared to have a jelly-like consistency, being easily removed by drawing bare fingers over it. (See Table I for analysis of Lake Winona water.)

Samples of this deposit or growth were collected and numerous tests were made on it, both chemical and bacteriological, in the purification plant laboratory. Samples were also sent to the laboratory of Wallace & Tiernan Co. in Newark, N. J., where they were examined by Mr. E. S. Horning of that firm. It was found that three types of organisms predominated, namely, large, gram positive, encapsulated bacteria; a smaller form of gram positive encapsulated bacteria, and the iron bacterium, Crenothrix. Photomicrographs of these various organisms were made and are shown in Plates I, II and III.

A Trial With Chloramination

The problem of removing this organic growth from the line was given very careful study. It was finally decided that the application of chlorine and ammonia at the head of the supply line presented the best available approach to the solution of this problem. Immediate steps were taken to provide treatment facilities at the lake. Due to the physical construction it was decided to install the treatment plant about 1,300 feet from the intake tower in the lake, utilizing in part a control valve house structure, located at this point. Facilities for the application of chlorine and ammonia were purchased and installed at a total cost of $15,000. No provision was made for treating the first 1,300 feet of line between the intake tower and the control valve house. This short stretch of line was of tunnel construction and we felt that periodic treatment of this short section would keep it clean.

The ammonia-chlorine treatment ("Chloramination") was begun on June 2, 1939, at a treatment rate of 1.26 ppm. of chlorine

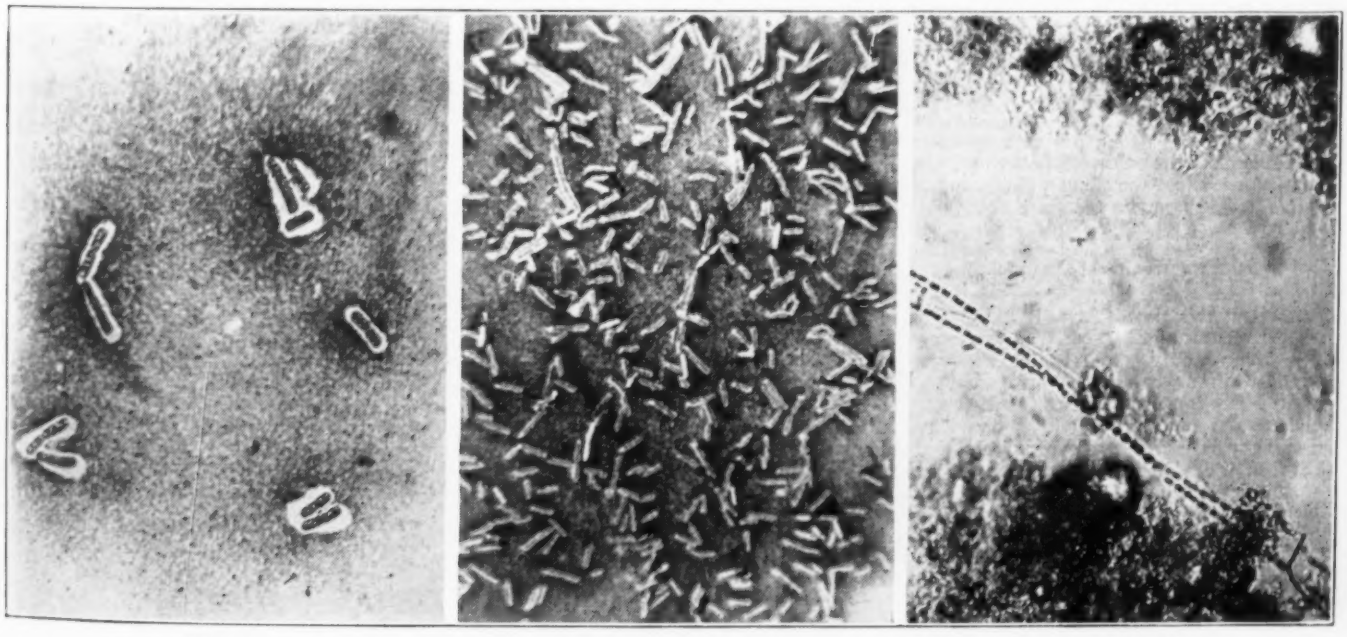


Plate I *Plate II* *Plate III*

Microphotographs of Organisms Found Predominating in Flow Impeding Slime on Pipe Interior Walls
Plate I and Plate II: Large and Small Gram Plus Capsulated Bacteria. Plate III: Crenothrix

Little Rock's 33-Mile Supply Line Under Construction

and one-third as much ammonia. At the end of the first three weeks of treatment, the capacity of the line, as measured by the Venturi meter, had increased from 20.38 to 21.80 mgd., but no "C" determinations were, as yet, made on the line. During this 3 weeks' period the residual chlorine reaching the 33 mile distant Filtration Plant in the city remained fairly constant at 0.55 ppm.

Prior to starting the ammonia-chlorine treatment, the "C" value of the line had been determined twice, on February 23, 1939, and again on May 25, 1939. These determinations were carried out empirically, dividing the entire line into seven sections and determining the "C" value of each section. From these results the average "C" value for the entire line was then computed.

During the next 30 day period (July 1-31, 1939) the 1:3 ratio of ammonia to chlorine was changed to 1:6 without changing the chlorine dosage. This did not affect the residual reaching the Filtration Plant, which remained at 0.55 ppm., but any further reduction in ammonia did result in a lower residual reaching the plant.

On July 31, 1939, friction coefficient determinations were made on the entire line under full flow conditions, and the "C" values for some sections showed noticeable improvement, the results being best nearest the point of chlorine application. The results of this and subsequent tests are shown in Table II.

Copper Sulphate Treatment Disappointing

At about this time (Aug. 1, 1939) a test on the 1,300 feet of line between Intake Tower and Control Valve House showed a "C" value of only 84. Since this section of line was not being treated with chlorine, the entire supply line was taken out of service, this section isolated, and treated heavily with copper sulphate and allowed to stand 48 hours in contact with the copper solution. [Here it is well to explain that an auxiliary reservoir floats on the supply line near the city, thus permitting holding the supply line out of service for considerable periods when necessary.] At the end of this time, the copper solution was thoroughly flushed out and the line put back in service, with the ammonia-chlorine treatment again being resumed. Subsequent tests on this section of the line showed no improvement due to the copper treatment.

Full flow tests were again made on the line on Aug. 11, 1939, and these indicated still further improvement in "C" values. At this time the chlorine dosage was increased to 1.60 ppm., with ammonia at 1:4 ratio.

On Aug. 14, 1939, strong chlorinous odors developed at the filtration plant. The chlorine dosage was immediately reduced to 1.0 ppm. and the ammonia ratio raised to 1:3. The chlorinous odors gradually disappeared over a period of 2-3 weeks.

On Oct. 2, 1939, the 1,300-foot Intake Tower-to-Control Valve House section of line was again isolated and this time treated with 30 ppm. of chlorine for a period of 48 hours. At the end of this time the line was flushed and the original ammonia-chlorine treatment resumed.

"Break-point" Process

On April 3, 1940, a full flow test was made on the entire line. The maximum capacity was found to have increased from 21.80 to 22.25 mgd. "C" tests on the 1,300-foot Intake Tower section showed great improvement. The "C" value for this section had been raised from 77 to 159. This indicated that straight chlorine treatment, in heavy concentration, should be highly effective in killing and dislodging the organic growth. It was, therefore, decided to discontinue the use of ammonia at the reservoir and to raise the chlorine dosage to "break-point" proportions. Laboratory tests had indicated the "break-point" of the raw lake water to be 3.5 ppm.

Break-point chlorination was begun on Aug. 5, 1940, using a chlorine dosage of 5.0 ppm. The residual reaching the filtration plant was, on the average, 1.0 ppm., the remaining 4.0 ppm. being dissipated in the line. At this time, tests were made at various points on the line to determine the chlorine residual present. The results of these and subsequent tests are shown in Chart I. Ammonia was still used in the purification processes, being applied to the already super-chlorinated water at the Filtration Plant at a 1:3 ratio, this ratio being based on the chlorine residual in the water arriving at the plant.

On Sept. 27, 1940, the chlorine dosage was reduced to 4.0 ppm., this reduction being occasioned by lower water temperatures and a lowered "break-point." ["Break-point" determinations have been made at various times during each year and have varied from a high of 3.5 ppm. in the summer to a low of 1.5 ppm. in the winter.]

Super-Super Chlorination Tried

Since the removal of the organic growth from the line was proceeding much slower than anticipated, at two different intervals during 1941 exceedingly heavy chlorine concentrations were employed for periods of 24 hours each. On these occasions, flow was reduced and the treatment rate was stepped up to 300-400 ppm., the heavily treated water being wasted into a creek near the Little Rock end of the line. The method used was to connect a battery of 4 one-ton chlorine containers into a large rubber hose manifold, which, in turn, was inserted into the pipe line through a pressure manhole near the reservoir. The flow through the line was kept at 10 mgd. during the time of treatment. At the end of the treatment the line was thoroughly flushed, put back into service and the original "break-point" treatment resumed.

On Oct. 21, 1940, a full-flow test was made on the line, the results of which indicated still further improvement in "C" values and maximum carrying capacity recorded since the beginning of the chlorine treatment.

On Oct. 27, 1940, the chlorine dosage was still further reduced to 3.0 ppm., and with few exceptions this treatment rate remained unchanged until Sept. 12, 1941, almost a year later. At this time it was increased to 3.5 ppm., where it remained until the end of 1941.

Chlorinating Station at Lake Winona Valve Control House
This station is fenced and guarded 24 hours per day by mountain men who know how to shoot. The area can be flooded with light by the throw of a series of switches

During the year 1941, four more full-flow tests were made on the line, each indicating still further slight increases in carrying capacity.

Flow tests, made on the line after these two superchlorination treatments, did not show any very great improvement, due to this type of treatment over and above the "break-point" dosage scheme.

Throughout the year of 1942 two full-flow tests on the line were made, the results still showing very slow improvement in maximum line capacity.

From January until June, 1942, the chlorine dosage was on the average 3.5 ppm. During the months of June, July and August the dosage was kept at 4.5 ppm. Since September the chlorine treatment rate has been slowly reduced and at the present time is 2.5 ppm.

The experimental stage of this treatment has been passed and our present plan is to keep well on the upper side of the "break-point," making the necessary seasonal increases or decreases as the "break-point" value of the raw water changes.

TABLE I

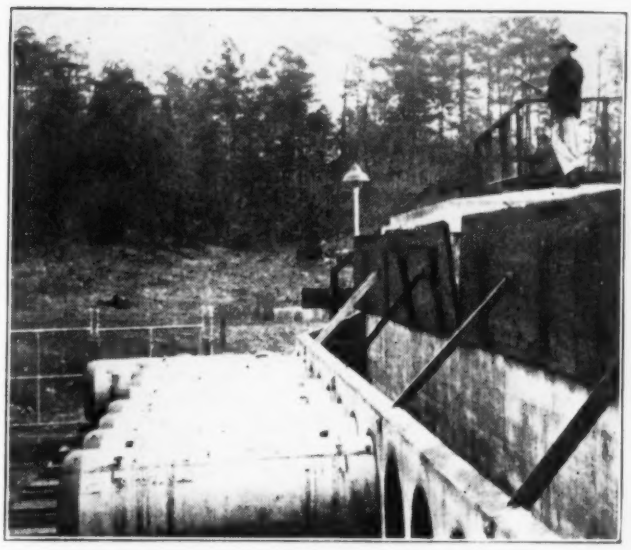
Raw Water Analysis—Little Rock, Ark.

(Lake Winona)

Component	ppm.
Silica (SiO_2)	5.60
Iron and Aluminum Oxides (Fe_2O_3 and Al_2O_3)	0.43
Calcium (Ca)	3.77
Magnesium (Mg)	1.26
Sodium and Potassium (Na K as Na)	3.04
Bicarbonate (HCO_3)	14.64
Carbonate (CO_3)	0
Sulphate (SO_4)	2.07
Chloride (Cl)	5.00
Carbonate Hardness	15.00
Total Hardness	15.00
Total Dissolved Solids	26.00

Advantages of "Break-point" Chlorination

Aside from destroying the organic growth in the transmission line, "break-point" chlorination has proved of value to us in other ways. Since beginning this treatment, taste and odor flare-ups have been practically non-existent. We are assured a sterile water throughout the entire plant and lactose-fermenting organisms in the plant are a thing of the past. The initial chlorine application to the line at the reservoir, followed by ammoniation only at the filtration plant, allows us to carry residuals of 0.3 to 0.5 ppm. out into the distribution system. Ample chlorination equipment is maintained at the filtration plant but its use is seldom required except at such times that the chlorine equipment at the reservoir is out of service for repairs, etc. Chlorine residual tests are made every hour by the operators at the filtration plant, thus assuring maximum safety in event of failure of the chlorination equipment at the reservoir.



One-Ton Chlorine Containers

Photograph shows how connections to containers and manifold gas line were protected against tampering before the station was guarded constantly. The valves in the container heads and manifold are inside the vault, the hinged covers to which can be padlocked down

Throughout the three years that this pipe line has been treated, numerous other tests, aside from those mentioned above, have been carried out. Probably the most significant of these were "Loss-on-Ignition" tests. This test was made on samples scraped from the interior wall of the line just prior to beginning the treatment and again after four months of treatment. The first sample showed a loss-on-ignition of 31.10 per cent and the sample collected four months later 20.61 per cent loss-on-ignition. During this four months' period the color of the organic growth changed from a reddish-black to a dirty grey-brown color.

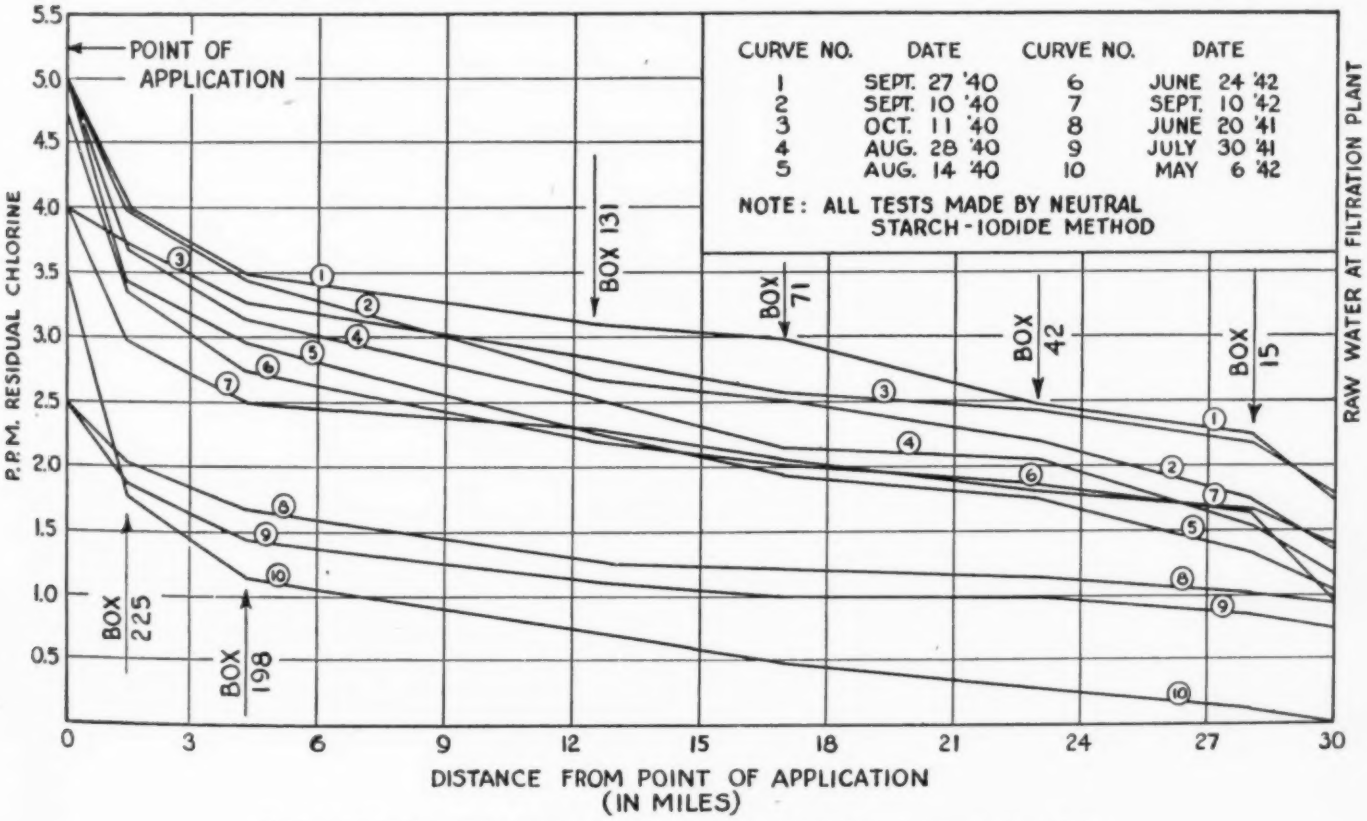
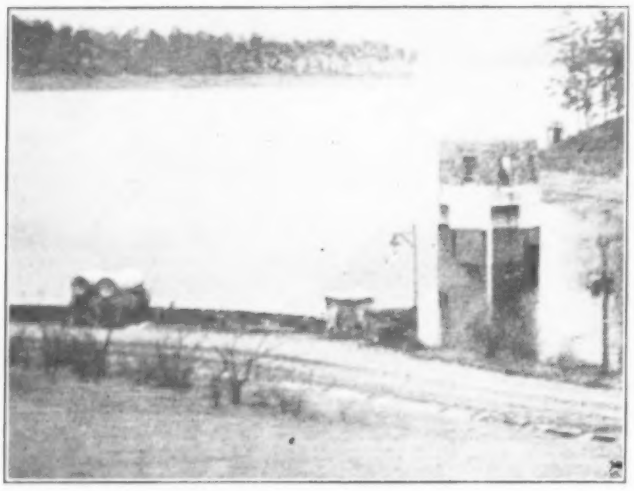
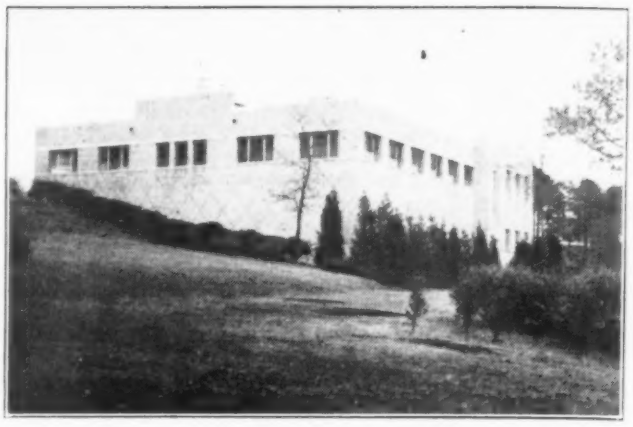


Chart I—"Break-point" Chlorination Test Results on 33 Mile Transmission Main



Intake Tower, Lake Winona
For temporary super-chlorination of tunnel section from tower to valve control house gas was fed direct from ton-containers through floating rubber hose line to the tower. The containers are seen in the lower left



Little Rock's 8 MGD. Filter Plant
Strategically located on a high hill-top within the city and in sight of the State Capitol.

Air-Scrubbing Possibilities

One interesting fact that was discovered by accident is the effect of a mixture of air and water in the flow line. Air was injected into the line in an attempt to airlock the pipe and thus build up pressure on that portion of the line ahead of the air. Although this was done in connection with another problem, it was noted that immediately after the addition of the air to the pipe line, numerous quantities of organic refuse were dislodged from the interior of the pipe and were carried into the plant. The picture of air and water creates turbulence, which apparently is very effective in scouring the organic matter from the pipe interior. We are considering utilizing this process for the purpose of dislodging more of the dead organic matter from the pipe line.

Summary

In one year of operation the capacity of a vital flow line was reduced 20 per cent by organic growth which could have been prevented had sterilization facilities at the head of the supply line been included in the original design.

Ammonia-chlorine treatment showed small and slow improvement and, therefore, was discontinued. From our three years' experience we are satisfied that "break-point" superchlorination has proven the most effective treatment and will probably be continued in varying degrees until the designed capacity of the line is completely restored.

TABLE II

Hazen-Williams Coef. "C" Determination—39-in. Raw Water Supply Line

Orig. "C" when installed = 147 for entire line
Original Maximum Flow = 25.32 Mgd.

Date	Intake Tower to Control House	Box 226	Box 198	Box 141	Box 71	Box 42	Box 15 (Junction)	Avg. "C" Ent. Line	Maximum Flow in MGD.
2-23-39	...	...	98	113	121	137	131	120	20.38
5-25-39	...	...	88	120	123	136	131	120	20.38
6- 2-39	Chloramine Treatment Started—1.0 ppm. chlorine plus 0.33 ppm. ammonia								
7-31-39	84	128	110	122	133		135	128	21.80
8-11-39	82	128	113	121	128	140	137	128	21.80
9-25-39	77	119	113	125	125	142	136	129	21.80
10- 2-39	Treated Intake Tower-Control House Line section with 30 ppm. chlorine (from Oct. 2-5th)								
4- 3-40	159	108	118	129	129	143	145	133	22.20
8- 5-40	144	117	117	129	127	133	139	128	22.20
8- 5-40	Ammonia discontinued; Super-chlorination begun. Treatment Rate—5.0 ppm.								
10-21-40	127	122	123	132	129	135	139	132	22.50
6- 5-41	116	121	120	130	134	135	141	132	22.80
6-21-41	Treated entire 39" line from Control House to Box 15 with 100 ppm. dosage of chlorine (12 hr. contact)								
6-27-41	107	125	121	132	135	136	142	134	23.03
8-18-41	118	120	120	134	135	137	142	134	22.89
10- 1-41	128	124	127	135	134	137	143	136	22.89
10-18-41	Treated entire 39" line from Control House to Box 15 with 100 ppm. dosage of chlorine (12 hr. contact)								
1-22-42	120.5	118.5	127	140	132	141	145	137	23.40
4- 6-42	139	118	124	136	137	144	146	137.6	23.70
11-12-42	108.6	130.3	128.1	138.6	133.7	139.1	144.5	137.0	23.5

PRACTICAL ELECTRICITY IN THE PLANT

The A. B. C.'s of Electricity for the Water and Sewage Works Man

By MARSDEN C. SMITH

Engineer and Supt. Water and Electricity, Department Public Utilities, Richmond, Va.

Taken from a series of short articles by Mr. Smith, dealing with the A.B.C.'s of practical electricity for water works and sewage plant operators.

The author, a graduate electrical engineer, is a well known water works operator. He is, thereby, peculiarly well qualified to present these discussions, which should be of considerable benefit to operators and designers less thoroughly grounded in electrical matters.

If there are points in his contributions not clear to the reader, Mr. Smith offers to answer inquiries.

THE increasing use of electricity in water and sewage treatment plants produces problems of design, operation and maintenance with which the engineer in charge is generally but little familiar. Fortunately, while advanced electrical engineering is a very involved subject, a helpful and useful knowledge of its fundamental principles can be obtained quite readily by the trained personnel of such plant. To that limited end the presentation of this series of articles is confined.

PART I—ELECTRICAL UNITS

The Volt

One of the most important units of electricity is the Volt. It is the unit of electrical *pressure*. Just as we measure water force or pressure in units of pounds per square inch or feet of head, the unit of electromotive (electric moving) force is the volt. In equations, its symbol is E. Voltage is sometimes expressed in print as the emf—abbreviation for electric-motive force.

Standard voltages are 110, 220, 440, 2,200, 4,400, and 13,200. The individual for whom these articles are intended is rarely concerned with voltages in excess of 2,200. Furthermore, the 110 volt standard is now in the process of change, and seems to be quite generally replaced by a standard of 120 volts.

Extra-heavy fittings and greater precautions are necessary with greater water pressures; so too, must greater care be taken both of life and property when higher electrical pressures are used. However, pressures of as little as 110 volts, in common domestic use, may prove fatal and care should always be taken to avoid personal contact with even these relatively low pressure circuits.

Most electrical apparatus is designed to operate at one of the above mentioned standard voltages. The use of other than these standards is both unnecessary and uneconomical. Incandescent lamps are generally rated at from 110 to 125 volts in five-volt increments. They may be obtained designed for 220 volts, but such lamps are not recommended except where no 110-volt service is available. Even then safety and economy demand the use of 110-volt lamps if possible.

Some Practical Considerations

Lamps are very sensitive to voltage change; and the operator should see that the lamps are purchased for the circuits on which they are to be used. For example, if the average voltage at the station is known to be 118 volts, 120-volt lamps should be used. Here the use of 110-volt lamps would increase the lamp replacement cost by almost 300 per cent.

Motors are not nearly so sensitive to voltage change as are lamps and will operate successfully at applied voltages within 10 per cent above or below normal rated voltage. Greater voltage variation will generally cause excessive heating and unsuccessful operation.

Small motors (less than 5 horse-power) are usually single phase and operate at standard lamp voltages. Large motors, 5 to 50 H.P., are cheaper when designed for 220 or 440 volts. Larger than 50 H.P. should be designed for 2,200 volts. Of course, local conditions may change these recommendations. One large plant has motors from 3 to 300 H.P. The station designers used 2,200 to 440-volt transformers; motors between 50 to 300 H.P. were ordered for 440 volts. A second set of transformers reduced the 440 volts to 220 volts for the smaller motors (up to 50 H.P.). Certainly this is unfortunate, because the larger and more expensive motors would have been of less first cost if designed for 2,200 volts, and the 2 to 5 per cent transformer losses, which materially increases operating costs, would have been saved. The smaller motors could all have been 440-volt type, thus here again would have been saved the second transformer losses. Here we see an evident error that a better understanding of the problem of electricity in design would have avoided.

Other than electrical engineers often fear the use of 2,200 volts. It is true, that there is no need for this higher potential, unless the size and number of motors justifies its use. However, where the total of as much as two or three hundred horse-power is required for motors larger than 50 H.P., the higher potentials are certainly advisable.

The relative advantage of the use of 220 or 440 volts as the operating voltage for the smaller motors is not so definite. However, for larger plants 440 volts seems more desirable. Safety requires the same care with 220 volts as with 440 volts, and a much wider range of motor sizes can be more economically operated at this than at 220 volts.

The Ampere

The second important unit of electricity to be considered is the Ampere.

It is the unit of electrical *rate of flow*. We are familiar with the various measures of the rate of flow of liquids; gallons per minute, etc.; so we should think of the unit rate of flow of electricity as the ampere. In equations its symbol is generally (I). In print Amperes are sometimes abbreviated to "Amp." Larger pipes are required to carry larger rates of flow of water economically; so too, larger wires are needed to carry larger currents (amperes) economically. Small pipes may be uneconomical because friction causes too great loss of water pressure. In exactly the same way, wires may be too small for the amperage (current flow) and cause an uneconomical loss of electrical pressure (voltage drop).

There are no standard currents as in the case for the voltage rating of electrical apparatus. Each appliance, lamps, heating devices, etc., takes from the circuit a current dependent upon its design and lack of resistance to flow. Motors require, for example, a current that varies with the load. All electrical apparatus (except lamps) should have its normal current rating stamped upon its nameplate. Lamp current is determined by dividing its watt rating by its rated voltage.

However, there are certain appliances such as wire, fuses and switches that are rated in terms of the current they may safely carry; thus currents are to this extent standardized. The plant manager should realize that these current ratings are fixed by the National Electric Code, and he should not permit greater current to flow through accessories than the limits established by this code. Oftentimes circuits are fused far beyond the rated capacity of the wire, which is supposedly being protected by the fuse. Such practice is both uneconomical and dangerous.

Most appliances, including motors, are connected between the supply lines, that is, in parallel. In this way the circuit voltage is impressed upon each appliance, causing a current to flow through the appliance of a quantity dependent upon its rating and load. These increments of current are added, hence the supply wires carry greater and greater total current as we work back toward the source of power. For example: Five 1,000-watt

lamps rated 100 volts each require 10 amperes. Let us designate these as numbers one to five, from that nearest the supply to the most remote. Both wires between the supply and the first (No. 1) lamp carry 50 amperes; between 1 and 2, 40 amperes, and so on until between 4 and 5 the current has reduced to 10 amperes, or that required by No. 5—the last lamp. They all have (practically) the same voltages as the supply applied to their terminals.

Some Practical Considerations

When installing new apparatus there are two considerations of great importance: (1) Use wire of ample conductor size. (2) Employ insulation having a large factor of safety. For low potential circuits (less than 600 volts) 30 per cent pure rubber insulation will generally prove more economical than the standard code insulation. Particularly is this true in water and sewage treatment plants due to the prevalence of dampness in such locations. For 2,200-volt circuits rubber insulated cable is more easily installed than is varnished cambric cables. Rubber depreciates much more rapidly when subjected to heat and grease or oil than does varnished cambric, but it is less affected by moisture. For this reason, varnished cambric is never used without some form of outer coating, usually lead. Modern synthetic resins and other compounds are rapidly proving their value for use as the outer protective coating, materially lessening the installation difficulties. These coatings are deserving of consideration.

In general, where expert electrical maintenance is not available, the proper thickness of 30 per cent pure-rubber insulation, on conductors of adequate size for the current they will ever have to carry, will certainly well repay the increased investment cost. Where such expert maintenance is available, varnished cambric insulation may prove better for 2,200-volt circuits.

The Ohm

The unit of electrical resistance is the Ohm. In equations its symbol is (R).

If we close the spigot, even though there be water pressure at the valve, no water can flow because the resistance is too great. The same result is obtained when opening an electric switch; the pressure (voltage) still exists but the resistance (ohms) become so great that no current (amperes) can flow. This is an example of localized resistance.

Electrical resistance may be distributed, in fact *is* distributed along the conductor just as is the pipe resistance to water flow proportional to its size, length and condition. Fortunately, in electrical circuits the loss of voltage (pressure) is always directly proportional to the resistance and rate of current flow. Therefore, the loss of power (to be discussed in the next article) is proportional to the resistance and the square of the rate of flow or current.

An electrical device, such as a lamp, does not use or destroy current in the sense that an oil lamp consumes oil, but by its relatively high resistance limits the current that may flow as a result of the impressed electromotive force—voltage. Thus we have the simple but important equation known as Ohm's Law:

$$E = RI \quad \ldots\ldots (1)$$

There are no standards of resistance; however, the established resistance per unit length of electrical conductors and resistance alloys may be found in any electrical engineer's handbook.

Direct vs. Alternating Current

Formula (1) applies to circuits that contain resistance only, or in which the frequency is zero, as in the case of direct current. This term frequency must now be understood. If the polarity between two wires (A and B) of a circuit is not changed, the current flow will always be in one direction in the wires, thus constituting what is termed direct-current—(D.C.). If we alternate wires A and B from one side of the source to the other, once each ½ second, the direction of current flow in A and B will reverse once every ½ second, and will begin to flow in the original or *same* direction in a given conductor once every second. Electrically we would say that there was being produced "An electromotive force (current) having a frequency of one cycle per second." Fundamentally that is the difference between alternating and direct currents. Modern alternating currents closely follow the sine law in their time-potential value; and the standard frequency in this country is now sixty cycles per second.

When direct current is applied to a coil of copper or other wire (having resistance R) wound around iron, if the current and voltage be carefully measured, equation 1 will be found to apply. When an alternating voltage is applied this equation no longer can be used. This is because any magnetic circuit is an inductive circuit, and the effect of an inductance is to divide the alternating current into two components which are at right angles to one another. Hence to obtain the same current through the coil when an alternating voltage is applied, a greater voltage is required than when a direct voltage is used. So for alternating current circuits equation 1 becomes:

$$E = ZI \quad \ldots\ldots (2)$$

in which Z is the impedance of the circuit.

Many devices, such as heating appliances and lamps have little or no inductance; hence may be used on either direct or alternating current circuits of the rated voltage; but inductive devices, such as transformers and motors, cannot be used on direct current circuits unless especially designed for the purpose.

Transformers

The engineer for whom these articles are intended rarely is concerned with the use of transformers; however, a brief discussion of them is advisable. The standard transformer consists of two stationary coils of wire insulated from one another and wound around a common iron core. A special class, the auto-transformer, commonly used for motor starters, has only one winding with connections to some desired turn between the two end turns.

Of the winding in the auto-transformers, the turns connected to the power supply is the primary; the secondary winding is connected to the load. The voltage change between the primary and secondary is in direct ratio to the number of turns used in the two windings; conversely, the current is in the inverse ratio to the number of turns. Hence a transformer may be used to increase voltage as readily as to reduce it—the so-called "step-down." Many deaths have resulted from opening the high voltage switch, assuming the transformer "dead," when in fact the 110-volt side was still energized thus producing normal high voltage in the primary.

Instrument transformers are especially designed to accurately reduce the potential or current, as the case may be, for metering and other purposes. Care should be taken to always connect the secondary terminals of current transformers together with wire (short-circuit them) if the secondary circuit must be disconnected for any purpose while the primary continues to carry current.

It is well to know that transformers, if kept cool enough, can safely carry much greater than rated loads. Cold winter weather and artificial ventilation around the tanks is effective, but hot locations and days are dangerous. Tank temperatures should never exceed 90 degrees C. Contamination of the oil by dirt or even traces of moisture must be avoided. In larger units the oil should be examined monthly by a competent inspector.

The Watt

Another very important unit of electricity is the Watt, which is the unit of electrical power. The more commonly used unit is the Kilowatt, which is one thousand watts. The symbol for the Watt is (W); for the Kilowatt (KW). The mechanical unit of power is horse-power; one horse-power (H.P.) is the equivalent of 746 watts or 0.746 kilowatts. Due to the fact that the efficiency of small motors is approximately 75 per cent, the input in kilowatts is, by coincidence, closely the same as the mechanical output in horse-power.

With direct current, electrical power is the product of the current (I) and the voltage (E). Thus we have:

$$P = EI \quad \ldots\ldots (3)$$

However, substituting for (E) from equation (1), wherein $E = RI$, we have:

$$P = RI^2 \quad \ldots\ldots (4)$$

Or similarly, substituting for (I) where $I = \frac{E}{R}$ in the same equation:

$$P = \frac{E^2}{R} \quad \ldots\ldots (5)$$

Now, it becomes evident that electrical power varies directly with both current and voltage, if resistance is not considered, but as the square of either (E or I) if the resistance is considered.

PART 2

POWER FACTOR; ITS SIGNIFICANCE

With alternating currents equation (3) becomes the more familiar form, and—

$$P = EI \cos \theta \quad \ldots\ldots (6)$$

In this equation the Cos θ is designated as the power-factor. If an alternating current circuit contains resistance only (no capacity or inductance) the angle θ becomes zero; hence, its

cosine, which is the power-factor becomes unity. Electrical installations in water and sewage treatment plants rarely contain sufficient capacity (condenser action) to be of any practical effect, hence we may omit further reference to "capacity" in these articles. Inductance, however, is of great importance, and in practical installations may reduce the power factor as much as 30 per cent.

The actual mathematical value of the power-factor of practical circuits is difficult to compute; however, it is well for the engineer to have some idea as to the values that may be expected. Incandescent lamps and heating devices, since they contain but little inductance, are virtually non-inductive; hence, their power-factor closely approaches unity. Motors and transformers vary through very wide limits. Of course, a transformer being highly inductive when delivering no load, its power-factor is quite near zero; but, at rated load the power-factor becomes quite nearly that of the circuit being supplied by the transformer. Small motors, up to 5 h.p., require power at not more than 60 per cent power-factor; particularly so when operating at light loads. Large induction motors, at full load, now may operate at as high as 94 per cent; and, synchronous motors, more fully discussed in coming articles, may be operated almost as desired.

The objection to low power-factors is that larger currents are required for the same power, thus increasing power losses in the whole electrical system. Furthermore, low power-factors cause much wider voltage variations than do greater loads with higher power-factors. For this reason many power companies offer reduced rates to those consumers whose apparatus constitutes a load having a favorable power-factor. This fact may be of value to many larger operators. It is true, however, that plant operators can exercise but limited control over the power-factor of their stations except through the selection and operation of the motors. This phase of the subject will be later discussed when motors and their characteristics are considered.

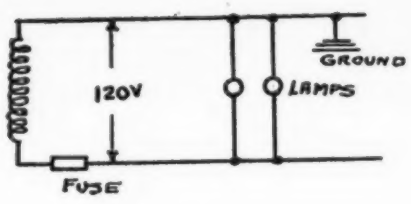


FIG 1

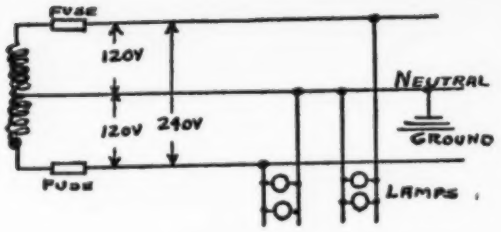


FIG 2

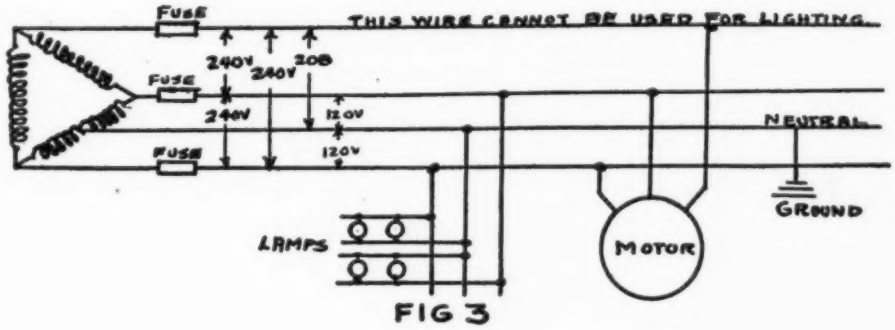


FIG 3

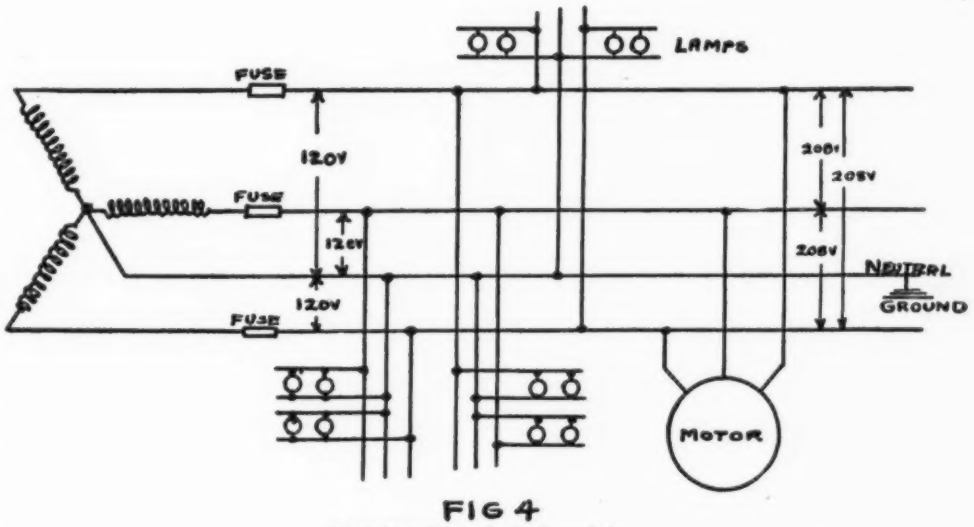


FIG 4

Circuits: Figs. 1, 2, 3 and 4

The Kilowatt-Hour

The kilowatt-hour (KwHr) is the unit by which electric power is generally sold. As its name implies, it is the average power consumed, in kilowatts, multiplied by the number of hours involved. For example: if an electric iron is operated for two hours at average rating of 600 watts, there is used $600 \times 2 = 1200$ watt-hours, or 1.2 KwHrs.

The volt-ampere (VA) is the product of the volts and amperes of a circuit or an appliance, without reference to power. Thus, the transformer is always rated in kilo-volt-amperes (KVA) because its parts can be designed for the voltage and current value desired, but the power-factor of its load may vary through wide limits. Thus we see that:

$$KW = KVA \times \text{Cos } \theta \quad \ldots\ldots\ldots\ldots\ldots\ldots (7)$$

Hence, if we are to know the safe load for a transformer rated at 100 KVA, we must first determine the power-factor of the load to be connected. If we may assume the load to be one-half lamps and one-half small motors; we may approximate the average power-factor to be 82 per cent. Hence, by equation (7) we find Kw = 100 × 0.82 (82 Kw) to be the safe load for this case.

The Cos θ, which we now recognize to be the power-factor, is actually the cosine of the angle of time-phase displacement between the current and the voltage of an alternating current circuit containing "capacity" or inductance.

Circuits

The term, "phase," is also applied to designate the circuits of an alternating current system. In the "Single-Phase" system the *voltages* are in the same time-phase in all parts of the system. In the "Two-Phase" system, the two voltages are 90 degrees apart. In the "Three-Phase" system they are 120 degrees apart.

In another sense, there are in effect one or two or three circuits in the single, the two or the three-phase systems. Of course, the power-factor may be different in each phase; hence the currents in the phases may not be of exactly the same angular difference as the voltages producing these currents.

The simplest circuit is that comprising the single-phase (two-wire) system, as in Fig. 1. This is used for the final branch circuit of larger systems, and in case of small loads, including most residences, it is always used.

The single-phase, three-wire system is next in capacity and in frequency of use. Single-phase, two-wire branches are connected thereto as shown in Fig. 2. The evident advantage of three wires over the two-wire system is that when loads are

balanced, the neutral carries no return current, hence the lamps and appliances operate at 120 volts, whereas the circuit operates at 240 volts. In this way twice as much power can be carried over the same wires, by merely adding one additional wire.

Grounding Practice

The neutral must be grounded. It should be the same size as the phase wires; and, it must *not* be fused or connected to any switch, and the wire used for the neutral must have white covering for identification, and the neutral must be connected to the white screw in all receptacles. In the single-phase, two-wire system one of the wires must be grounded and the same rules as given for the neutral conductor wire must be observed.

(Grounding practice as it affects water works piping will be given some discussion at a later point in this article.)

Three-Phase Standard for Heavy Duty

The three-phase (three-wire) system is standard for motor loads. If lighting is required, the neutral of one transformer (made larger to carry the additional load) is brought out as in Fig. 3. Most power companies limit the single-phase load that may thus be supplied to 50 KVA. In addition, this method of supplying the lighting loads makes service interruptions more frequent because of the necessity for grounding one of the transformer windings. Perhaps most serious of all is the objectionable flicker in the lights obtained when starting motors, particularly elevators connected to the system. Of course, economy often rules and hence this system is frequently used; but unless the motors are relatively small, and are started very infrequently; it is undoubtedly better to separate the lighting and very small motors from the power system.

The formula for power in the different systems, with balanced load, is given in the following table:

System	*Power*		*Max. Volts to Ground*
Single-Phase (Two-Wire)	$P = EI\cos\theta$	Here E=120	120
Single-Phase (Three-Wire)	$P = EI\cos\theta$	Here E=240	120
Two-Phase (Four-Wire)	$P = 2EI\cos\theta$	Here E=120	120
Three-Phase (Delta)	$P = \sqrt{3}EI\cos\theta$	Here E=240	207.8*
Three-Phase (Y)	$P = \sqrt{3}EI\cos\theta$	Here E=207.8	120

*Volts to ground on lighting circuits is 120.

The two-phase (four-wire) system is so little used that no discussion is necessary.

PART 3—CIRCUIT PROTECTION

Fuses and all electrical circuit-breakers are similar in function to the safety valve on a boiler; and hence they should be seriously considered. They are all intended to open the circuit, thus stopping the flow of current, should the current exceed a predetermined or dangerous rate through these safety devices.

While the problem of circuit protection becomes at times quite involved, still there is much that can here be discussed to advantage. In the first place, the Natinal Electric Code is now almost universally accepted as the authority for the safe utilization of electricity in all except central station systems. Consequently, the engineer should obtain a copy of this useful and important publication.

Fuses and Circuit Breakers

Fuses are the cheapest and simplest of ali protective devices. They consist of a piece of relatively high resistance alloy wire or tape, designed to melt, and thereby part, at the current at which the fuse is rated. The wire is enclosed in a suitable flame-proof case to prevent ignition of surrounding materials at the time the fuse flashes and melts. The use of fuses is now confined almost entirely to circuits the importance of which does not justify the more expensive and accurate devices. The type now approved, known as the "refillable type," permits the renewal of the fuse link, using the expensive part (the cartridge) over and over again.

For those applications in which the replacement of fuses is frequently necessary, thermal relays or air circuit breakers are to be recommended. Motor circuits fall in this classification. Thermal relays and circuit breakers can permit a greater than rated current pass for a short time, as during the starting period of a motor, and therefore are of especial advantage for this service. The current capacity as well as the voltage ratings of this class of protective devices are limited, and when greater limits are needed the oil circuit breaker must be used.

The oil used in circuit breakers must be especially selected for this service; and no other oil should ever be used. This precaution is essential for the reason that the oil must have high insulation value, high flash point, low carbon content, and wide temperature viscosity constant—all in order to quickly quench the arc that is formed with each opening of the contacts.

Relays

The overload operation of an oil circuit breaker is usually actuated by an auxiliary device known as a relay. Relays may be of several types: the instantaneous, the inverse time limit, and others. The modern relays are truly marvelous devices; however, the types needed by the water works plants are, in the main:

(1) *The Instantaneous Type*—dash-potted relays with direct mechanical trip. Here a coil which carries all or a definite part of the load current raises a solenoid when the current flow exceeds a predetermined value. The rising solenoid mechanically releases a trigger, which in turn permits the oil circuit breaker to open. An oil-filled dash-pot retards the solenoid movement. The dash-pot opening is adjustable, hence the time for opening with a given over-current can be selected as desired. The oil in the dash-pot should be inspected at intervals and replaced if dirt or sludge has accumulated. While rather crude, this device is sufficiently accurate for the protection of most small motor circuits.

(2) *The Air Bellows Type*—This type is not much used now. An air bellows, with an adjustable escape valve, is substituted for the oil dash-pot described above.

(3) *The Induction Type*—This relay is more expensive than those above mentioned, but its use is justified in the protection of all important cicuits.

With the induction relay, when the current exceeds the desired value, the torque on an aluminum disc, mounted on the same shaft with the relay contacts, causes the shaft to rotate. Such rotation causes the opening (some cases the closing) of the relay contacts, which in turn electrically energize the main tripping coil on the circuit breaker. The advantage of this type is that the time of opening the main circuit breaker can be determined to a fraction of a second; also, that the limits of control are so wide that these relays, with suitable current transformers, become almost universally applicable and highly accurate protective devices.

To repeat, too much care cannot be given the subject of circuit protection. Over-fusing (use of fuses with too great capacity) of circuits is dangerous and uneconomical. Noting a too frequent operation of the overload, protection of any appliance warrants prompt investigation. The source of the trouble should be remedied by correction, rather than following the easiest path of using too large circuit protection to overcome an annoying operating circumstance.

Grounding—Its Essentiality

It is no exaggeration to say that without adequate grounding, satisfactory electrical service would be virtually unknown. In addition, safety would be a word more than a reality. Even so, many groundings are so deficient in quality as to become actually a hazard instead of a safety effect. Many persons have been swindled into paying for a false sense of security when installing lightning rods having many ornamental glass balls but no grounds. Thereby the victim is actually inviting the lightning to strike the house but offering no protection by way of a cable or rod to conduct the electric discharge into the earth and there dissipate it.

Grounds should be carefully made. Use not less than No. 2 B&S gauge copper wire. Several grounds are preferable to a single ground in order to lessen the chances of broken connections. Use the water pipe system; the larger the pipe, the better. Do not use the gas, gasoline or oil pipe lines. Be sure the connection between the wire and pipe is electrically and mechanically as perfect as possible. If no pipe system is available, drive at least three 1¼-inch pipe, or equivalent copper rods, *well below the moisture line* in the earth. A good test is that the driven ground connection, when shorted, should blow a 30-ampere fuse at 120 volts.

Much discussion has recently been raised in the water works field as to the effects of attaching the electric circuit "neutral" wires to the water pipes. There is no question that the damage done to water systems by stray direct currents, as from street railways, has been indeed enormous. Here we have electrolysis at its worst, and the destruction of the metallic pipes at spots where the current leaves the pipes is rapid. This condition is inexcusable and should be prohibited everywhere.

However, in the alternating current system the damage is not so evident, and many doubt its *real* existence—or at least its seriousness. Also it is quite possible that were all connections between electrical and water systems removed, electrical service as we know it today would be a thing of the past. And even should such action force the electric companies to seek other means of obtaining the necessary protection now provided by these ground-

ing attachments, the water systems would be subject to the same distress now *debatedly* suffered. It would seem certain that more severe difficulties would be caused by the same currents finding their way to the water system in a then uncontrolled routing and dissipation which present practices have been designed to effect.

The necessity for grounding the electric circuits is to prevent dangerous high-potential voltages (through mistakes or accidental contact) from increasing the normally low-potential circuits to a dangerous loading. The wiring for lighting systems of buildings is designed for a maximum of 150 volts to ground. Let us assume that a street series circuit operating at 5,000 volts should fall across the service wires from the pole to your home. With no ground on the "neutral" of your secondary wiring, its potential would be raised from its normal low value to a maximum of 5,000 volts. Certainly something must happen; either a fire is started, or perhaps a member of your family may be killed. The effect of such danger has been observed when service thawing current reaches the house wiring. In these instances the "ground" has worked in reverse, but proves its safety value and the necessity of "breaking" the service line before electrical thawing is started. Now consider these same conditions to exist, except that now your "neutral" is properly grounded. When the high-potential circuit is now temporarily crossed with service, the high-potential currents are safely carried to ground, and no one in the home would realize the possible disaster that the ground connections have avoided.

When, What and Why Ground?

It is certainly to be hoped that from study there will result a greater care in the preparation and arrangement of ground connections between the electric and water systems, and that the volume of curent flow be intelligently regulated. We, the water utility interests, should not embarrass this effort by hasty demands to prohibit all grounding to water systems. As a matter of fact, we could not do so, even if thoughtless enough to demand such.

[Water works men have themselves found difficulty in effectively grounding pumping station motor circuits by any other method than an efficient connection to their own pressure mains leaving the station.—Ed.]

No wires used in lighting systems should have more than 150 volts to ground. The wires of power circuits, such as 220 or 440 volts, *should not be grounded.* All appliances, frames of motors, conduit, etc., in addition to the "neutrals" of lighting systems, should be carefully and effectively grounded. Inspect grounds frequently. The snuffing out of a life may be the penalty if you do not. Satisfactory operation is another, if secondary, reason for so doing.

PART 4—MOTORS

Alternating current motors are of two general types: the synchronous and induction. The main difference between these two types is that, while the synchronous motor can run only at a definite constant speed (synchronous speed), the induction motor must operate at a speed dependent upon the load applied, but never at synchronous speed. There are other important differences that, to better advantage, will be mentioned later.

Synchronous Type

At a given frequency the speed of a synchronous motor may be determined by the equation;

$$N = \frac{120f}{P} \quad \ldots\ldots\ldots (8)$$

in which N = revolutions of rotor per minute (RPM); f = frequency in cycles per second; P = number of poles.

Since the standard frequency is 60 cycles per second, equation 8 is generally expressed in the form:

$$N = \frac{7200}{P} \quad \ldots\ldots\ldots (9)$$

From this it is evident that the maximum speed for a 60 cycle motor is 7200/2 or 3600 RPM, and the speed, N, from equations 8 or 9 is known as the synchronous speed of the motor. This, for 60 cycle motors, is the constant 7200 divided by the number of poles; and, since the number of poles must be an even number, synchronous speeds become 3600, 1800, 1200, 900....RPM. One of the greatest limitations of the synchronous motor is that it cannot be built to operate at other than synchronous speeds, whe- oftentimes an intermediate speed is needed.

On the other hand, the fact that it runs at an exact speed is quite frequently its greatest asset. Electric clocks and timing devices depend upon this characteristic for their value and dependability as to accuracy. Pump drives, and mechanical devices of all types that require an exact and fixed speed, necessitate the use of the synchronous motor for this reason.

Another marked difference between the synchronous and induction motor is that the former requires salient magnetic poles, excited (magnetized) from a source of direct current; whereas, the induction motor has no such poles and requires no separate excitation. In fact, the standard squirrel-cage motor is well named, because its rotor is essentially nothing more than a circle of bars parallel to the shaft which are held in place and short-circuited by two metallic rings. Picture the revolving cage for the squirrel's exercise and you have it—thus, the name.

Unfavorable Characteristics

The necessity for this auxiliary direct current is indeed unfortunate, because direct current generators are difficult to maintain. Hence, greater skill and maintenance are required for synchronous than for induction motor operation. Then, too, the starting characteristics of the synchronous motor are rarely satisfactory. The starting torque (that is, the twist or pull) cannot approach that of the induction motor; frequently necessitating expensive and complicated methods of holding the load off the motor until it has reached full speed. Fortunately, centrifugal pumps may frequently be started under no-load without inconvenience, which renders this deficiency of the synchronous motor of no real importance.

Favorable Characteristics

On the favorable side of the ledger, the synchronous motor does possess the ability to operate with a "leading" power factor, contrasted to the rather decidedly "lagging" power factor of the standard induction motor. As has been stated previously, many power companies offer a lower rate to consumers whose requirements make permissible a desirable power factor. Where this is the case, the ability of the synchronous motor to operate at the "leading" power factor may have influence in the selection of the type of motor to be adopted.

From the above, it can be seen why, for water works and sewage treatment plants, the use of synchronous motors is frequently advised against. They are only to be considered when exact speed is essential or power costs may be lowered appreciably by the favorable power factor. Even then, the engineer will do well to be certain that savings in power bills will offset the increased operating difficulties that are certain to be realized in the use of synchronous motors.

Induction Type

The induction motor differs from the synchronous type in that it requires no separate excitation, and its ability to operate at a variable speed, as contrasted to the constant speed synchronous motor.

At no load an induction motor will run almost up to its synchronous speed. It should be understood that while the induction motor has no salient poles, the stator is wound to produce two, four or any even number of poles, just as is the stator of a synchronous motor; hence it has a synchronous speed of 3600, 1800, 900 RPM, just as does the synchronous type.

As the load on an induction motor is increased, the speed gradually lessens until at full rated load the speed is reduced from two to four per cent of its synchronous speed. Thus a given motor may have a synchronous speed of 1200 RPM, a no load speed of 1199 RPM and a full load speed of only 1170 RPM. If the load is further increased, the "slip" (as the loss of speed is called) will increase until a definite value is reached, at which point the motor will come to a stop. This load is known as the "pull-out" load.

Favorable Characteristics

Standard induction motors have very favorable starting characteristics, requiring relatively a small starting current and producing 200 or more per cent of full load torque. They are the most rugged and reliable of all motors. But while they will successfully operate under most adverse conditions, reasonable care should be taken to keep the air ducts and windings free from lint and dirt. The oil in the bearings must be flushed and changed at least once each year.

Smaller and specially designed induction motors require no starting device, and may be started by applying normal full voltage. Larger motors require reduced voltage for starting, which is

usually obtained from auto-transformers, called starting compensators. Two coils, each on an iron core, are connected open-delta across the three-phase lines; a 40, 50 or 60 per cent tap is taken to the motors for starting. After the motor has started and reached a constant speed, the compensator is disconnected and full voltage goes to the motor.

Variable Speed Motors

The wound-rotor induction motor, for operating at variable speeds, is not so rugged as is the standard squirrel-cage type. It is more expensive and also usually less efficient. A misunderstanding of the speed characteristics of these motors has caused no end of trouble. We may gain a clear conception of the speed variation of the wound rotor, induction type motor if we think in terms of "slip." As stated above, the standard squirrel-cage motor "slip" varies from virtually nothing at no load to about 3 per cent at full load. With the wound rotor, external resistance may be added to the rotor circuit, the effort of which is to *increase* the slip. Hence, this motor will run at essentially *constant* speed at no load, regardless of the amount of external resistance introduced in the rotor circuit. But, as the load is applied, and the greater is the external resistance, the more rapidly will the speed drop off.

Practically, this means that if we desire to drive a centrifugal pump at a variable speed, in order to vary the head and quantity delivered, we must first learn from the pump manufacturer both the speed and the horse-power required by the pump for each value of head-quantity desired. This data is then furnished the manufacturer of the motor who will design the external rotor resistances so that the various controller positions will connect the correct resistance to cause the speed to be that needed for the pump to operate under the desired condition.

Since power is a product of speed and torque, it should be remembered that less horse-power output can be obtained from a motor operating at a reduced speed than at its normal full speed. The reduction in motor output is approximately proportional to the reduction in speed. This fact should be considered at the time of purchase in order to be certain that the motor will not be excessively heated when operating at any of the reduced speeds. The same resistors that serve for speed control are also used for starting, hence no compensator is required as is the case for some of the standard squirrel-cage types.

Motor Ratings

The rating of most electrical apparatus such as motors, transformers, etc., is based upon the temperature rise that will occur when the device is operated continuously under normal full load and normal voltage conditions. Many manufacturers recommend a limit of fifty-five degrees centigrade rise, while others base their estimates upon a rise of only forty degrees. After all, this simply means that a given motor rated at 100 HP, at 40 degree rise would be rated at 125 HP at 55 degree rise. All things considered, it seems to be the consensus of opinion, and dictate of wisdom, that all important motors in water works and sewage treatment plants should be purchased for a guaranteed rise, not to exceed forty degrees centigrade.

THERMAL CONDUCTIVITY OF INSULATING MATERIALS*

The measure of heat loss, sometimes called the k-factor, is given below. The *smaller* this constant is for a given material *the better the insulating properties* of the material.

Heating requirements are measured by engineers in "degree-days." Degree-days are published in heating handbooks and in United States Weather Bureau reports for nearly every city in the United States and Canada. One degree below 65 degrees F. for a 24-hour period equals 1 degree-day.

MATERIAL	DENSITY, lbs./cu. ft.	CONDUCTIVITY** (mean temp.) (90 deg. F.)
Air space between walls (3½ in.)	.081	.86 to 1.10
Cotton	.65 to 6.25	.21 to .29
Pure wool	6.24	.26 to .32
Silk	6.24	.28 to .34
Hair felt	13.0	.36 ..
Flax fiber	13.0	.31 to .33
Cork, ground	8.1	.27 to .31
Sugarcane fibers	13.5	.34 ..
Pine wood	34.3	.8 to 1.0
Wood pulp board, plaster base	16.2	.3 to .4
Mineral wool	2 to 7	.27 to .30
Magnesia (85% magnesia, 15% asbestos)	13-16	.40 to .46
Expanded vermiculite	6 to 7	.38 to .48
Diatomite powder	10.6	.3 to .5
Diatomite blocks	28.1	.58 ..
Pumice gravel	18.8	.64 ..
Tile (clay and plaster)	12.7	.60 ..
Glass, plate	15.5	3.6 to 7.3
Bricks, dry	125.0	3.0 to 6.0
Brickwork (mortar bond)	132.0	4.0 to 5.0
Gypsum plaster	46.2	2.0 to 5.0
Concrete, 1-2-4	150.0	5.0 to 9.0
Slate shingles	162 to 205	10.0 to 10.4
Building stone	165.0	12.5 ..
Steel (1 percent carbon)	489.0	314.0 to 328.0
Copper (pure)	553.0	2,580.0 to 2,670.0
Silver (greatest conductivity)	655.0	2,860.0 to 2,920.0

*Authorities: National Bureau of Standards, Federal Housing Administration, and various university and research laboratories.

**Conductivity—British thermal units transmitted per hour per square foot of material 1 inch thick, per degree F. difference in temperature of the two faces.

WEIGHTS PER CUBIC FOOT OF DRY CHEMICALS USED IN WATER & SEWAGE WORKS

Chemical	Type	Weight per Cu. Ft.
Activated Alum	Ground	60 lbs.
Aluminum Sulphate	Powder	38 to 45 lbs.
	Ground	60 to 63 lbs.
	Lump	62 to 67 lbs.
Ammonium Aluminum Sulfate	Powder	58 to 62 lbs.
	Nut	60 to 64 lbs.
	Lump	64 to 68 lbs.
Black Alum	Ground	54 lbs.
Carbon (Activated)	Powder	*15 lbs.
Clay (Bentonite)	200 Mesh	50 lbs.
Copper Sulphate	Powder	64 lbs.
	Snow	85 lbs.
	Granular	90 lbs.
	Medium	80 lbs.
	Large	73 lbs.
Disodium Phosphate	Crystal	60 to 64 lbs.
	Anhyd. Powder	58 to 62 lbs.
	Flake	50 to 54 lbs.
Ferri-Floc		72 lbs.
Ferrisul		72 lbs.
Ferrous Sulphate	Sugar Crystal	62 to 66 lbs.
Hydrated Lime	Powder	*40 to 45 lbs.
Potassium Aluminum Sulphate	Powder	58 to 62 lbs.
	Nut	60 to 64 lbs.
	Lump	64 to 68 lbs.
Quicklime	Lump	60 to 70 lbs.
	Pulverized	80 lbs.
Soda Ash 58%	Light	*35 lbs.
	Dense	65 lbs.
Sodium Aluminate	Powder	*40 to 50 lbs.
Sodium Bisulfite (Anhyd.)	Powder	72 to 76 lbs.
Sodium Fluoride	Special Light	*38 to 42 lbs.
	Light	48 to 52 lbs.
	Dense	67 to 75 lbs.
Sodium Sulfate	Crystal	58 to 64 lbs.
	Needle	46 to 52 lbs.
	Powder (Anhyd.)	78 to 86 lbs.
Sodium Sulfite	Powder (Anhyd.)	80 to 90 lbs.
Sodium Thiosulphate	Granular	59 to 63 lbs.
	Fine, Cryst.	68 to 71 lbs.
	Coarse, Cryst.	54 to 58 lbs.
Tri-Sodium Phosphate	Ground	59 to 63 lbs.
	Med., Cryst.	56 to 60 lbs.
	Coarse, Cryst.	54 to 58 lbs.

*Requires hopper agitation.

(Courtesy R. J. Leveque, Sales Mgr., Omega Machine Co.)

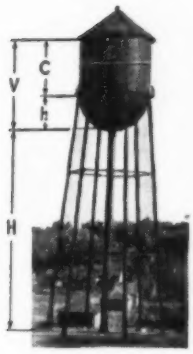
PITTSBURGH-DES MOINES STEEL CO.

Tanks—Plate Fabrication—Structural Steel

Plants at: 3418 NEVILLE ISLAND, PITTSBURGH, PA. . . . 919 TUTTLE ST., DES MOINES, IA. . . . 625 ALVISO RD., SANTA CLARA, CAL.
Other Sales Offices at: ROOM 918—270 BROADWAY, NEW YORK . . . 1222 FIRST NATIONAL BANK BLDG., CHICAGO, ILL. . . . 1223 PRAETORIAN BLDG., DALLAS, TEX.

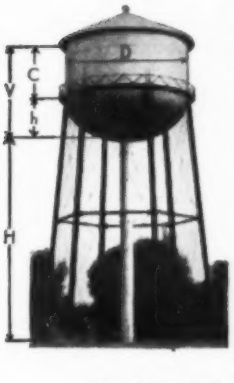
In these tables we have compiled—in compact but complete form—data on steel reservoirs and on the various types of elevated steel tanks. For information as to the application of these various types of tanks, for designs for specifications, or for estimates—write our nearest office.

Table I—Pittsburgh-Des Moines Standard Hemispherical Bottom Elevated Tanks



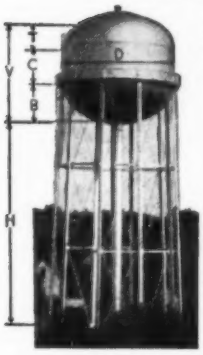
Capacity in U.S. Gallons	Tank Dimensions D ft.	C ft. in.	V ft. in.	H = Height of Tower to Bottom of Tank Capacity ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
5,000	9	10 0	11 3	11 3	18 9	31 9	38 3	51 9	58 9	72 9	79 9	93 9	100 9	.....	.....	
10,000	13	5 11	11 11	10 0	20 0	30 0	40 0	50 0	60 0	70 0	80 0	90 0	100 0	.....	.....	
15,000	13	10 11	16 11	10 0	20 0	30 0	40 0	50 0	60 0	70 0	80 0	90 0	100 0	.....	.....	
20,000	13	15 11	21 11	10 0	20 0	30 0	40 0	50 0	60 0	70 0	80 0	90 0	100 0	.....	.....	
25,000	15	14 7	19 11	44 8	50 0	69 8	75 0	.....	94 8	100 0	.....	125 0	.....	.....	.....	
30,000	15	18 5	23 9	44 8	50 0	69 8	75 0	.....	94 8	100 0	.....	125 0	.....	.....	.....	
40,000	17	18 5	25 1	46 8	.....	.....	75 0	.....	96 3	100 0	.....	125 0	.....	.....	.....	
50,000	19	17 7	25 7	.....	55 0	63 4	75 0	83 4	91 8	100 0	111 8	120 0	128 4	140 0	148 4	
60,000	19	22 6	30 6	.....	55 0	63 4	75 0	83 4	91 8	100 0	111 8	120 0	128 4	140 0	148 4	
75,000	21	22 6	30 6	.....	55 0	63 4	75 0	83 4	91 8	100 0	111 8	120 0	128 4	140 0	148 4	
100,000	24	22 6	31 0	.....	50 0	63 1	75 0	79 7	91 6	100 0	113 1	116 6	125 0	141 6	153 4	
150,000	28	24 2	34 7	46 6	54 10	63 2	75 0	83 4	91 8	100 0	111 10	120 2	128 6	140 3	148 7	
200,000	32	23 4	36 1	45 9	54 1	62 5	75 0	83 4	91 8	100 0	112 7	120 11	129 3	141 10	150 2	
250,000	32	31 4	45 4	45 4	53 8	62 0	75 0	83 4	91 8	100 0	113 0	121 4	129 8	142 8	151 0	
300,000	36	28 4	42 5	45 4	53 8	62 0	75 0	83 4	91 8	100 0	113 0	121 4	129 8	142 9	151 1	
400,000	40	30 0	46 6	44 6	52 10	61 2	75 0	83 4	91 8	100 0	113 10	122 2	130 6	138 10	152 8	
500,000	44	29 9	49 2	43 6	51 10	60 2	75 0	83 4	91 8	100 0	114 10	123 2	131 6	139 10	154 7	
600,000	44	38 6	58 2	} Tower heights have not been standardized for these capacities and can therefore be built to suit the requirements in each particular case.												
750,000	50	34 9	57 5													
1,000,000	50	52 0	73 9													

Table II—Pittsburgh-Des Moines Standard Hemi-ellipsoidal Bottom Elevated Tanks



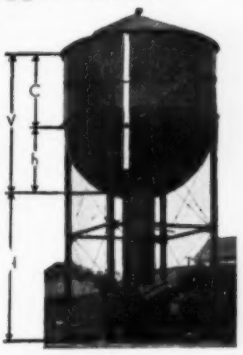
Capacity in U.S. Gallons	Tank Dimensions D ft.	C ft. in.	V ft. in.	H = Height of Tower to Bottom of Tank Capacity ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
25,000	17	11 9	15 5	46 4	51 8	71 4	75 0	.....	96 4	100 0	.....	126 8	.....	.....	.....	
30,000	17	14 7	18 6	46 1	51 5	71 1	75 0	.....	96 1	100 0	.....	126 5	.....	.....	.....	
40,000	21	11 3	16 9	47 5	.....	.....	75 0	.....	97 5	100 0	.....	126 2	.....	.....	.....	
50,000	22	13 2	19 0	.....	57 2	65 6	75 0	85 6	93 10	100 0	113 10	122 2	130 6	142 2	150 6	
60,000	24	12 10	19 4	.....	56 6	64 10	75 0	84 8	93 2	100 0	113 2	121 6	129 10	141 6	149 10	
75,000	26	13 6	20 8	.....	55 10	64 2	75 0	84 2	92 6	100 0	112 6	120 10	129 2	140 10	149 2	
100,000	28	16 2	23 2	.....	51 6	64 7	75 0	81 1	93 0	100 0	114 7	118 0	126 6	143 0	154 10	
150,000	34	14 10	25 0	46 9	55 1	63 5	75 0	83 7	91 11	100 0	112 1	120 5	128 9	140 6	148 10	
200,000	38	15 5	27 0	46 11	55 3	63 7	75 0	84 6	92 0	100 0	113 9	122 1	130 5	143 0	151 4	
250,000	40	18 1	30 0	47 5	55 9	64 1	75 0	85 5	93 9	100 0	115 1	123 5	131 9	140 1	153 1	
300,000	40	23 11	34 0	49 4	57 8	66 0	75 0	87 4	95 8	100 0	117 0	125 4	133 8	142 0	155 0	
400,000	46	22 9	34 11	48 10	57 2	65 6	75 0	87 8	96 0	100 0	118 2	126 6	134 10	143 2	157 0	
500,000	50	23 9	37 0	49 8	58 0	66 4	75 0	81 2	89 6	100 0	112 8	121 1	129 4	146 0	152 8	
600,000	55	21 9	39 7	} Tower heights have not been standardized for these capacities and can therefore be built to suit the requirements in each particular case.												
750,000	60	22 4	42 4													
1,000,000	60	35 0	54 0													
1,000,000	65	26 1	47 7													
1,250,000	79	17 4	43 4													
1,500,000	70	37 8	60 0													
1,500,000	79	24 0	50 0													
2,000,000	90' 3"	22 6	50 0													

Table III—Double Ellipsoidal Tanks



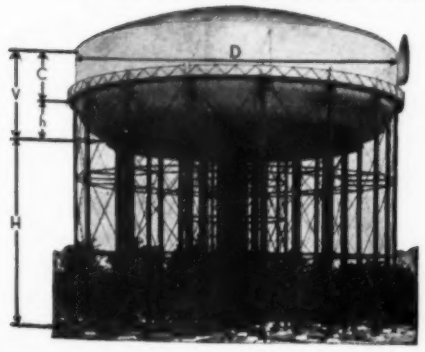
Capacity in U.S. Gallons	D	B	C	T	V	H
50,000	22'-0"	5'-10"	9'-4"	4'-4"	19'-6"	
75,000	26'-6"	7'-0"	9'-0"	5'-0"	21'-0"	
100,000	28'-0"	7'-0"	11'-1"	5'-7"	23'-8"	
150,000	34'-0"	10'-0"	8'-8"	6'-10"	25'-6"	
200,000	36'-0"	9'-0"	12'-11"	6'-9"	28'-8"	Built
250,000	40'-0"	10' 4"	11'-7"	7'-6"	29'-5"	
275,000	40'-0"	11'-11"	13'-9"	7'-6"	33'-2"	to
300,000	40'-0"	8'-7"	17'-11"	7'-6"	34'-0"	
350,000	44'-0"	14'-8"	13'-10"	8'-0"	36'-6"	Order
400,000	46'-0"	12'-2"	14'-9"	8'-8"	35'-7"	
500,000	50'-0"	15'-0"	14'-6"	9'-8"	39'-2"	
600,000	55'-0"	14'-4"	14'-0"	10'-0"	38'-4"	
750,000	60'-0"	15'-11"	12'-7"	11'-6"	40'-0"	
1,000,000	65'-0"	21'-8"	15'-9"	11'-0"	48'-5"	

Table IV—Railroad Type Tanks



Capacity in U.S. Gallons	Tank Dimensions D ft.	C ft.	C in.	V ft.	V in.	H
20,000	15	10	9	16	2	
25,000	15	14	7	19	11	Any
30,000	17	12	7	19	0	height
40,000	19	13	1	20	6	from
50,000	21	13	1	21	1	15' 0"
60,000	24	10	1	20	3	to
75,000	24	15	1	23	10	40' 0"
100,000	28	13	5	23	7	in
150,000	28	14	2	24	7	multi-
200,000	36	15	1	29	2	ples
250,000	38	17	3	33	3	of
300,000	38	23	11	38	3	5' 0"

Table V—Toroidal Bottom Tanks



Capacity in U. S. Gallons	Tank Diameter (D) when h = 10' 0" and V = 20' 0" ft.	in.	V = 25' 0" ft.	in.	V = 30' 0" ft.	in.	V = 35' 0" ft.	in.	H
750,000	82	0	73	2	66	8	61	8	
1,000,000	94	5	84	3	76	9	71	0	
1,250,000	105	4	94	0	85	8	79	2	Built
1,500,000	115	2	102	9	93	9	86	8	to
2,000,000	132	8	118	5	108	0	99	11	Order
2,500,000	148	0	132	3	120	7	111	6	
3,000,000	162	0	144	8	131	11	122	1	
4,000,000	186	8	166	9	152	2	140	9	
5,000,000	208	6	186	3	169	11	157	3	

Table VI—Steel Reservoirs

Capacity in U.S. Gallons	Diameter ft.	Heights ft.	in
50,000	20	21	6
60,000	22	21	6
75,000	24	22	6
100,000	26	25	6
150,000	30	28	9
200,000	34	29	9
250,000	38	29	9
300,000	42	29	3
400,000	46	32	6
500,000	50	34	6
750,000	60	35	9
1,000,000	70	35	0
1,500,000	80	40	3
2,000,000	95	38	3
2,500,000	110	35	6
3,000,000	120	35	9
4,000,000	130	40	9

R. D. COLE MANUFACTURING CO.

Est. 1854

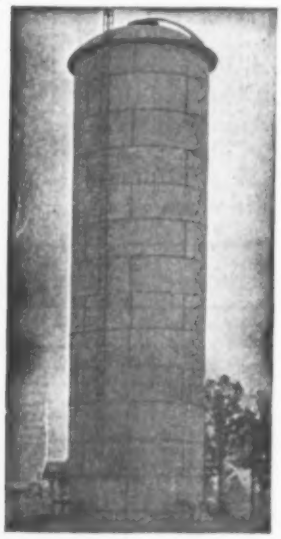
Tanks, Towers, and Steel Plate Work

NEWMAN, GA.

5,000 TO 2,000,000-GALLON WATER TANKS

All shapes and sizes—The R. D. COLE MANUFACTURING CO. has developed a complete line of elevated steel tanks for water supply, both for domestic service and sprinkler requirements, ranging in capacity from 5,000 to 2,000,000 gallons.

The designs include the standard Hemispherical Self-supporting Bottom, the "Cole Ovaloid," Standpipe and many individual styles involving architectural treatment to satisfy local conditions, or to provide special shapes for advertising purposes.



STORAGE TANKS

Pressure tanks for storage of gas from digesters at sewage disposal plants so that excess output at peak loads can be used during off-peak periods. Chemical storage tanks, hot water storage tanks, tanks for bulk storage of oils and gas.

Designs Available for Any Service

1,000,000-Gallon "Cole-Shallow Depth" Tank

CONSTRUCTION FACILITIES

Fabricated Steel Plate—The R. D. COLE MANUFACTURING CO. has a fully equipped plant for the fabrication of riveted or welded steel plate. In addition to the construction of its regular line of horizontal return tubular boilers, oil storage tanks, tubular heaters, etc., the company is prepared to construct special tanks and apparatus of any specified metal plate.

Alloys and Lining for Processing Apparatus—The facilities and experience of the company enable it to fabricate special apparatus of all kinds for the processing industry using alloy steel plates, stainless steel, nickel-clad steel, etc., or linings such as lead, tin, nickel or Monel.

MAINTENANCE OF ELEVATED TANKS

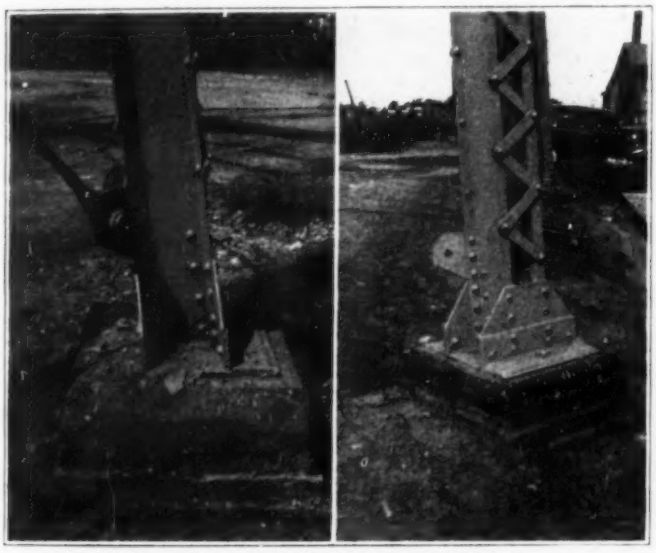
By JOHN M. PERRYMAN

Engineer, R. D. Cole Manufacturing Co., Newnan, Ga.

TANKS and towers are an important part of most water supply and fire protection systems, and should receive the same care and attention as other important parts of such systems.

It is generally known that corrosion of iron and steel is a silent enemy, working during both war and peace through all the years. The conversion of steel into iron oxide or rust is Nature's course in returning iron or steel into its original state.

Air and water coming into contact with steel starts this cycle of returning iron and steel to rust. Rust occupies more space and also weighs more than the steel destroyed, for it consists of hydrous iron-oxide which is 54 per cent iron, 20 per cent oxygen and 26 per cent water. Due to capillary action water will climb a rusty steel tank shell or column, regardless of its height. Corrosion of steel tanks can be caused and accelerated by the presence of acid fumes in the air, and particularly are tanks in large industrial areas thus affected. Also tanks located in areas of high humidity and along coastal waters, where high salt bearing vapors are present, are subject to accelerated rusting.



This Tank Has a Nice New Coat of Paint. But— an inspection by a qualified man would have avoided a dangerous condition. In very poor condition, the base of this recently painted tank was not given needed attention. It was not cleaned properly before painting and the base plate should have been grouted to shed water, prevent corrosion and frost spalling.

Another Bad Base Condition The base structure has been cleaned and painted but the brick foundation is badly in need of repairs. This picture also reveals the hazardous practice of removing the lower tower rods.

Surface Preparation

Tanks should be protected at all times from the elements that cause rust, using a paint that will protect the surface and present a favorable appearance. Steel can be protected at a reasonable cost by the use of rust inhibitive steel coatings. In preparing the surface the use of expensive sand-blasting is not necessary, nor chipping to the bare metal. The use of hand or power driven wire brushes is really all the preparation that is essential. The simple method of removing loose paint, scale and dirt by hand brushing, then applying a rust-inhibitor to seal the steel from the atmosphere will protect and prolong the life of your structure

Loadings on Tower Members

As an example of the heavy loadings, on the tank tower structure, I might mention the 2,000,000 gallon tank in Charleston, S. C. The water and metal loading exceeds the weight of 6,000 Ford cars, and the 100,000 gallon tank at Mt. Pleasant, S. C., amounts to 325 Ford cars. You can see from this that the tower load involved in overhead tanks is appreciable, and must be dealt with according to a scientific, businesslike procedure.

The Inspection

To assure long life and prevent, as nearly as practicable, the formation of rust, and in addition provide a safe structure, the tank should be drained completely, allowed to dry, and inspected by a competent inspector at intervals not to exceed five years.

These inspections should be made by no other than a skilled man who is thoroughly competent to detect weaknesses and pass upon their importance. This is not a matter which can be left to transient steeplejacks or traveling inspectors of unknown ability and integrity—the man should be a structural engineer. In locations where the water is highly aerated or contains particularly corrosive elements, the examination should be made more frequently than once in five years.

When an inspection is to be made, the fire chief and others dependent upon the water supply should be notified in order that they may not be dependent upon the tank for extra head and volume during the planned outage.

What to Look For

The inspection should consist of: first, an examination of all ladders for safety; especially examine for missing connecting bolts, conditions of lugs and rungs, etc. The revolving ladder on the roof should be inspected for a poor connection at the finial, also the ladders on the inside of the tank and rise should come in for thorough examination. Check condition of the roof and spider, and be sure that it will prevent the entrance of birds and other harmful matter, and that it will safely withstand sudden high winds Examine the tank proper for loose scale and leaky rivets and seams.

The balcony floor is designed to resist the thrust of the columns and should be perforated at proper places so that water will not stand on the floor. Examine the hand rail for safety, also all rods, turnbuckles, clevises and pins.

Repairs and Replacements

Before repainting you should be certain that all badly corroded parts have been replaced or properly repaired. Look *under* the clevis pins and rod loops on your tank. The top side may be in excellent condition, but *the underside and partially hidden section may be found to be in a dangerous condition.* Examine the back surfaces of lattice bars, anchor bolts, the inside of boxed channel columns, pockets where batten plate connections and column bases form pockets for collecting trash and water without proper drainage. These enclosures may be cleaned and

Some Bad Order Specimens

(Left) Lattice bars completely eaten away where building roof contacts the tower leg.

(Center) Another specimen of badly corroded tower leg.

(Right) This obsolete style of tower leg has all but failed. It buckled under the full load weight.

painted, then filled with concrete to a proper level at the top and shaped to shed water. Base plates should be grouted with sand and road oil mixed, or with asphalt.

Where angles or othter structural sections are separated by narrow spaces, rust can usually be removed by using narrow, bent scrapers, and the sides of the angles facing the narrow space may be painted with a spray gun. The present day manufacturer of elevated tanks endeavors to offer a tank design using open sections that can be readily inspected, cleaned and maintained.

If structural members or details affecting the strength of the tower are found to be in a condition such that they must be replaced, they should be renewed by a *recognized* tank designer, fabricator and *skilled* erectors. Diagonal wind rods should not be removed for cleaning and repairing, except when the tank is empty and on a calm day, and then only when adequate provision has been made by means of struts and guy wires to prevent a possible collapse of the structure.

An Important Hole to Keep Open

The arrow points to the weep hole in the boxed-in column section to drain water from this type of base.

The bases and base plates must be examined, and if the base is so built that it holds water (see illustration), drill a 1¼-inch hole through the channel boxed section to permit drainage. Trash should be removed at regular intervals. The base plates should be grouted with a mixture of sand and asphalt so water cannot run under the plates. The grout should taper off from top edge of plate to concrete pier.

There are a number of elevated tanks built with auxiliary tanks of smaller capacity suspended underneath, also flat bottom tanks built on supporting grillage. When these tanks are inspected, look for badly corroded suspension rods and connections to the tank. They quite often are found in a dangerous condition. The steel grillage on flat bottom tanks is subject to heavy corrosion and only on careful examination will you find those connections that have become unsafe. There have recently been some tanks found in dangerous condition that were originally built without balconies and not sufficient reinforcing at the column connections. The shell plates have actually broken, due to over-stressing and fatigue of the metal.

Concerning Rivets and Seams

Much has been said about leaking rivets and seams. The facts are that in most cases the importance of this is exaggerated and sometimes used by unscrupulous repairmen as an entry and excuse for expensive repair work.

Loose rivets can be caulked just as effectively as can leaky seams. Don't let anyone tell you that because the head of a rivet is badly pitted that it must be removed and a new one driven. Remember that a rivet head is to hold the plates firmly together, and though the tension is diminished somewhat by rust, the strength of the structure is not seriously impaired. *It is the shank of the rivet that really does the job.* Furthermore, when a rivet is knocked out, you loosen at least eight additional adjoining rivets, thus a larger repair job has been created. Be careful!

Cleaning

After all of the above procedure has been carried out, the tank should be thoroughly cleaned both inside and outside, as well as the tower and other parts of the structure. Paint or mill scale which adheres firmly to uncorroded steel should *not* be removed, but these surfaces should be cleaned to remove all loose dirt or sediment. Where extensive pitting of the steel beneath several coats of paint is encountered, this portion should be vigorously wire brushed with a power tool to prepare properly for the new coat of paint.

If the tank has a large steel riser (36-inch diameter or larger), all sediment can be removed from the base by the means of the washout valve in the base of such risers. However, if the tank has a small cast iron or steel riser of from, say, 8 to 12 inches, it will be necessary to bail the sediment from the bottom of the tank, since these tanks are in general without washout valves.

Remember to repack the expansion joint and replace all brittle and leaking gaskets at manholes. Frostproof casings should be repaired or replaced; or, even better, remove both pipe and casing and have a 36-inch steel riser installed in its place if the size of the installation will justify it.

Painting

Best results from painting are obtained when the outside temperature is above 50 F. and the temperature of the paint and surface to be painted are the same. Painters should be cautioned not to allow trash, paint or other material to drop down the riser while they are cleaning or painting. A sheet of heavy paper may be tied over the small riser, or a deck may be built across a large riser pipe.

Interior

During the summer it is best to paint tank interiors at night in order to avoid uncomfortably high temperatures. Paint dries more quickly on the inside if the manhole cover is removed and the roof hatch is left open. Forced air circulation has a definite advantage in expediting the painting job, and it should be remembered that forced circulation adds greatly to protection of the painters and accelerates drying.

It is recommended that the inside of the tank, riser and underside of the roof be painted with two complete coats of red lead and a final coat of black interior tank finish. This finishing coat should be of the type that does not impart any taste, odor, or discoloration to the water.

The coat of black interior tank finish is actually to protect the red lead, and, of course, the red lead is to protect the steel.

Exterior

Paints tend to loose their imperviousness when submerged in water for long periods, such as on the inside of tanks. It is suggested that 10 per cent by weight of litharge be added to resist the softening action and hasten the drying. The litharge may be mixed in a small amount of linseed oil and then added to the red lead as required.

The outside should be painted with a coat of either red lead or gray lead, followed by two coats of aluminum. It is also suggested that you paint all abraised surfaces with two touch-up coats prior to the finish painting with aluminum.

For best results, the final coat inside the tank should be allowed to dry *at least one week* before admitting water.

Safety and Cleanliness

Paint thinned with naphtha, benzol, toluol or other liquids which give off toxic vapors are hazardous to life when used in confined spaces such as inside of a tank. They should be used only by experienced painters who are thoroughly familiar with their proper applications and the hazards involved. Forced air circulation inside the tank and gas masks are essential where such dangerous materials are employed.

After painting, particular care should be taken to make sure that all planks, scaffolding, rope, paint cans, brushes, and other material are removed from inside the tank and riser. This having been done, you should refill the tank, sterilize it in accordance with the Board of Health requirements, and restore service as soon as possible, considering good workmanship and proper drying as the first essentials.

Foundations should be examined, and if showing signs of deterioration should be carefully pointed up with a cement mix consisting of one part cement and one part of sand. There have been a number of foundation piers built of brick or stone. These should receive extra attention.

A typical specification for tank painting follows, and we believe that it will eliminate any possibility of the tank owner suffering from some unscrupulous contractor, holding him responsible for charges other than cleaning and painting, unless such extras are authorized in writing. Your attention is further directed to the practice made by most tank fabricators and erectors of making tank inspections at a nominal charge and

giving a written report of work that, in their opinion, is actually necessary.

REPAINTING ELEVATED TANKS
(A Pattern for Specifications)

Bids are to be received for the furnishing of the necessary labor, tools, equipment and materials to clean and paint Elevated Steel Water Tank and on a steel tower elevating the bottom Steel Tower of ——— gallons capacity —— ft. —— in. above top of foundations, and/or Flat Bottom Steel Water Reservoir of ——— diameter x ——— height.

General: The inside of the tank proper and underside of roof is to be carefully examined and all loose paint, scale, rust and blisters are to be removed with scrapers and power wire brushes and the surfaces thoroughly dried. Paint or mill scale which adheres firmly to uncorroded steel need not be removed, but the surface should be cleaned to remove sediment and dirt. If there is extensive pitting of the steel, this is to be brought to the attention of the inspector for whom the work is being done.

The spider rods, inside ladder, or any oher inside structural details, such as the inside of the large steel riser pipe, is to be thoroughly cleaned as previously mentioned before any paint is applied.

All dirt and sediment collecting at the base of the riser is to be removed.

Any brittle or leaking gaskets at the manhole, washout valve or other openings are to be replaced with new gaskets of equal or better materials.

The inside of the tank and large steel riser after being prepared as heretofore mentioned and approved by the inspector, are to be given one coat of red lead paint with 10 per cent by weight litharge added to offer resistance to softening action of the water and dry more quickly. After this red lead coat has become thoroughly dry, a coat of black interior tank finish paint is to be applied on the inside for the finish coat.

The outside of the tank is to be examined and cleaned as indicated for the inside, with especial attention being given to those parts of the tank structure which are difficult to clean, such as around the clevice pins and end of diagonal wind rods, anchor bolts or back surfaces of lattice bars or columns, inside channel columns near foundations, inside surface of members composed of angles which are separated by thin lattice bars, washers or short pipe.

If members or details effecting the strength of the structure are found seriously corroded, this should be brought to the attention of the inspector. Diagonal wind rods or other members should not be removed for cleaning, unless the tank is empty and adequate provision is made to prevent the structure from collapsing.

After the outside has been thoroughly cleaned, a touch-up coat of red lead is to be applied to all surfaces where the paint has been removed, and then the entire outside of the tank and tower is to be given two coats of aluminum paint of color selected by the purchaser and of a kind made purposely for application to outside of steel water tanks.

The contractor for this work is not to apply any paint, unless the outside temperature is above 50 degrees, and paint and surface of the steel should be approximately the same temperature.

Provision is to be made for the safety of the men, providing proper ventilation for working on the inside, and comply fully with all local and state laws; Workmen's Compensation, Public Liability and Property Damage Insurance are to be carried with $10,000.00 and $25,000.00 limits.

Certified copies of policies in force to be attached to contract.

The contractor is to employ only skilled elevated tank painters, and no other work except the above cleaning and painting is to be done, except with written approval.

Upon completion of the painting, the contractor is to remove or dispose of all rubbish or other unsightly material caused by their operation and leave the premises in as good condition as it was found.

Terms of payment: Net cash on completion and acceptance of work.

Additional Comments

Tanks with small cast iron risers and wooden frost casings should be examined and expansion joints repacked.

If hot water or steam pipes are in poor condition, they should be replaced.

Consult your insurance company and advise them when the tank will be out of service and length of time out of service.

If the tank is a municipal water supply unit, notify the local fire authorities when the tank will be out of service, so they will not be dependent on this volume of water for fire protection.

MAKING PIPE BUSHINGS FROM STANDARD PIPE

A Handy Kink

DO YOU know that first class pipe bushings can be made out of standard pipe? Many users of pipe don't know that it can be done. Or, if they know that it can be done they don't know the correct size of drill to use for tapping. I have occasionally made bushings out of pipe, but each time I found it necessary to first look into my handbook for the drill size to use and that is so much trouble that it is frequently easier to go to the store and buy a new bushing. Recently, though, I collected all of the data together for all bushings that can be made out of ordinary sizes of extra heavy and double extra heavy piping, compiled the figures in tabular form, and here they are.

For example, to bush from ¼" to ⅛" get a piece of ¼" extra heavy pipe sufficiently long for cutting the outside thread. Then cut the end off to the desired length, drill or ream with a 21/64" drill (diameter of drill 0.328") and then tap with a ⅛" pipe tap. That's all there is to it.

This accompanying table tells the complete story for all ordinary sizes: Note that in one case, ⅜" to ¼", the internal diameter of ⅜" extra heavy pipe is such that no drilling is necessary.

Note also that in bushing from ½" to ⅜" either extra heavy or double extra heavy piping can be used.

To Bush From	Use This Size Pipe	Use This Size Drill or Reamer
¼" to ⅛"	¼" X	21/64" drill = 0.328"
⅜" to ¼"	⅜" X	None.
½" to ⅛"	½" XX	21/64" drill = 0.328"
½" to ¼"	½" XX	27/64" drill = 0.422"
½" to ⅜"	½" XX	9/16" drill = 0.562"
½" to ⅜"	½" X	9/16" drill = 0.562"
¾" to ⅜"	¾" XX	9/16" drill = 0.562"
¾" to ½"	¾" XX	11/16" drill = 0.688"
1 " to ¾"	1 " XX	29/32" drill = 0.907"
1¼" to 1 "	1¼" XX	1/18" drill = 1.125"
1½" to 1 "	1½" XX	1/18" drill = 1.125"
1½" to 1¼"	1½" XX	1-15/32" drill = 1.468"
2 " to 1½"	2 " XX	1-23/32" drill = 1.72 "
2½" to 2 "	2½" XX	2- 3/16" drill = 2.187"
3 " to 2½"	3 " XX	2- 9/16" drill = 2.562"
3½" to 3 "	3½" XX	3- 3/16" drill = 3.187"
4 " to 3½"	4 " XX	3-11/16" drill = 3.688"
4½" to 4 "	4½" XX	4- 3/16" drill = 4.187"
	X = extra heavy pipe. XX = double extra heavy pipe.	

REPAINTING STEEL WATER TANKS*

(With Notes on Repairs)

THE appended material constitutes an outline for use in preparing repainting specifications. In using this outline, it will be necessary for the purchaser to insert the requirements for the number of coats to be applied and the kind and color of paint. These are variables, which depend upon the condition of the surface to be painted, the type of existing coating and the color. *Since these are "painting" specifications only, no reference is made to cathodic protection, which is, however, applicable to old as well as new tanks.*

Frequency of Painting

To assure long life and to prevent the formation of deep-seated rust or corrosion, steel tanks should be thoroughly inspected both inside and out at intervals not exceeding five or six years. Where paint is exposed to unusually severe atmospheric conditions or to corrosive water, more frequent inspection and repainting will be necessary.

Number of Coats

If the old paint is in fair condition, only one coat may be required. It will probably be found, however, that, after cleaning, certain portions of the steel will be bare; these should be painted with a spot or patch coat before the finish coat is applied. If the surface is generally in bad condition, a complete primer coat should be substituted for the patch coat, in which event a total of two coats will be required on the entire structure. The extent of the painting or number of coats should be specified by the purchaser.

Inside of Tank

Experience has shown that, in practically all cases, the inside surfaces of a water tank are in worse condition than the outside. Almost without exception, tank bottoms which have had to be replaced on account of leaks through the steel, have corroded through from the inside. It is vitally important that the inside of a tank be painted as often as the exterior; and, if the water stored is particularly corrosive, the interior may have to be painted at more frequent intervals.

Kind of Paint

Underwater exposure involves very severe service for paint. The paint which, in general, has given the best results for this service is red lead and linseed oil paint (*weighing 21 to 24 lb. per gal.*) containing small amounts of lithargic, which acts as a hardener. This has not, however, been satisfactory for certain waters. Asphalt paints have been found suitable for some waters, but quite unsuitable for others. *Coal-tar enamels have also been widely used with generally satisfactory results where ice formation is not a factor.* More recently the newly developed synthetic resin type of paint has given good results under many conditions. Where experience with red lead and linseed oil paints containing litharge has been unsatisfactory, it is recommended that consideration be given to the alternate types. Where red lead and oil paints are used, it is not necessary to apply a finished coat over the red lead and the same paint may be used if a second coat is specified. In the event that two coats are necessary, however, a small amount of lamp black should be added to the second coat in order to give a darker shade and in this way to make it easier to determine whether the first coat has been entirely covered by the second.

If the old paint on the outside of the tank is black or dark green, a graphite paint may be used for the exterior surfaces. If the old paint is aluminum or a light colored paint, unless it is in fair condition, it may be necessary to apply two coats to insure a good finished appearance. If the final color desired is dark, the two coats may be necessary to cover the old light paint. If the final desired color is light gray, cream or some similar light color, the two coats will probably be necessary, as light paints do not have as good *hiding* power as dark paints. The paint used for the patch coat should be red lead or a similar suitable primer paint. If the finish coat is dark, the red lead for the patch coat should be darkened by the addition of lampblack, so that the patch areas may be successfully covered.

It is not the intention in these suggestions to recommend any particular brand or manufacturer of paints. The purchaser should consult *the tank manufacturer from whom the tank was purchased* or a reliable paint manufacturer of his own selection and determine which kind, quality and composition of paint to use, specifying the use for which it is intended.

Repairs

If any consideration is to be given to repairs to a tank at the time that it is being painted, the representative of a firm engaged in the installation of elevated water storage tanks should be called and directed to inspect the existing structure. *Non contract related to repainting water storage tanks should have made a part of it any agreement related to repair work unless a prior inspection of the tank has been made and the extent of and cost of the repairs is recorded in an aggregate figure.* Certain unscrupulous painting and repair firms have solicited painting work and, after inspection of the structure, have represented to the owner that expensive repairs were necessary. Quite frequently such firms have removed hundreds of perfectly good rivets in order to replace them at so much per rivet, or per hour.

Rivets

For a great many years it was the custom for tank manufacturers to drive tank rivets with flat heads on the inside. After a number of years a flat-head rivet, which may have rusted to some extent, appears to have lost the major portion of its head, when, in reality, only a small part has disappeared and the rivet has many years of life left. As rivets do their work in shear and as there is very little tension force in a rivet, the head can rust entirely away before replacement is necessary. As long as a rivet stays in its hole, it fulfills its function and does not have to be replaced.

Spider Rods

In the building of an elevated tank, it is the builder's custom to place rods across the top of the tank shell, under the roof, like spokes of a wheel. These are known as spider rods. As they are located near the high-water line and are alternately wet and dry, corrosion is severe and they may rust out long before the inside surfaces of the tank have been severely attacked. These rods are used for erection purposes only and may be removed, if desired, without harm to the structure. The tank builder does not recommend their replacement if they rust out. A tank repair man may claim the tank is in need of extensive repairs, after showing the owner these rusted rods. *Beware of the repair firm using the condition of the spider rods as a basis for recommending repairs.*

Leaks

If there are leaks in a tank, they may be of three kinds:

The first type is the leak through an expansion joint of a tank having the older type of cast-iron riser and wooden frost case. The remedy consists of repacking the expansion joint.

The second type is the leak at a calked joint or rivet head. Unless corrosion at this point is severe, this leak can be stopped by the use of ordinary hand calking tools.

The third type is a leak right through the plate at a point where a pit hole has eaten its way through. Such a leak may *ordinarily* exists only in the case of a very old tank or one which has not been cleaned and painted on the inside for about twenty years, *although there are rare cases of pit penetration in a shorter time due to electrolytic action or very corrosive water. In these cases the water should be analyzed and a check made to locate stray currents.* A temporary repair may be effected by the use of a patch bolt. Such a leak indicates that the entire bottom may be thin and other leaks may soon appear. The use of welding to patch such leaks is of very doubtful economy, as the heat of welding very often is the cause of new leaks. Even if a considerable area is welded, it may be but a short time after such repairs are made before new leaks appear. The only entirely satisfactory cure is the replacement of the entire bottom. This should be done by the manufacturer or by a regular tank construction company. If it is desired to postpone such replacement, leaks may be temporarily stopped with patch bolts as they appear and such repair may suffice for a few years.

Inspections

When a large water tank reached twenty years of age or more

*From Tentative Recommended Practice—Repainting Elevated Steel Tanks and Water Storage Tanks by the American Water Works Association—Jour. A.W.W.A., July 1943.

and the owner suspects that maintenance has not been of the best, it would be advisable to have a complete inspection made. Usually the tank manufacturer has experienced men for this service, who, for a nominal charge, will submit a report showing the condition of all parts of the structure. In case of doubt as to the need of repairs, the manufacturer should be consulted.

Precautions

In painting the interiors of closed tanks, adequate ventilation should be provided to remove fumes and prevent injury to workmen or the possibility of accumulating volatile gases.

PROPOSED SPECIFICATIONS FOR REPAINTING ELEVATED STEEL TANKS AND WATER STORAGE TANKS

1. General

The contractor shall furnish all labor, machinery, tools, rigging, brushes and all cleaning and painting materials necessary to clean and paint the structure in strict conformity with the requirements of these specifications.

(If owner elects to furnish the paint, it shall be so stated at this point.)

2. Cleaning

All dirt, rust, loose mill scale and loose paint shall be removed by means of scrapers and wire brushes. *Special care shall be used to clean all pits and roughened areas.* If any rust forms on the cleaned surface it shall be entirely removed before any paint is applied.

All rust, scale and sediment collecting inside of the tank bottom shall be entirely removed and the inside surfaces swept clean. In the case of elevated tanks, such rust, scale, etc., shall be lowered to the ground by means of a bucket and rope.

(*If the condition of the steel surface is such that the above means are incapable of properly cleaning the steel and sandblasting must be resorted to ,paragraph 3, below, shall be used in place of paragraph 2.*)

3. Cleaning by Sandblast

If cleaning, as outlined under paragraph 2 above, is not effective, sandblast shall be used. In such case, the sandblast equipment shall be in good working condition and shall have ample capacity to furnish the required volume of compressed air at sufficient pressure to operate the sandblast effectively. The sand used shall be largely composed of silica grains and shall be sharp and as coarse as it is practicable to use. Provision shall be made to prevent the spreading of sand to adjoining property. All rust, mill scale, grease or other material shall be removed from the steel so as to expose the bright metal over the entire surface to be cleaned. No more area shall be sandblasted than can be painted on the same day that the cleaning is done. If rust forms on the cleaned surface, from any cause, it shall be removed before any paint is applied.

4. Quality of Paint

The paint to be used shall be ready-mixed and shall arrive at the job in the original sealed cans or drums, bearing the manufacturer's name. *Two pounds* of litharge shall be added to *each gallon* of red lead paint used on submerged surfaces. *Litharge shall be added only to such quantity of paint as will be applied within the half day following. No paint containing litharge shall be used if it has stood overnight.*

The brand or manufacturer of the paint shall be as agreed upon between the purchaser and contractor, it being understood that only the best grade of paint, from well known, reliable paint manufacturers, will be used. No paint shall be applied until approved by the authorized representative of the customer. Heavy pigment paints shall be well stirred each time before paint is withdrawn from a large container. If the pigment shows a tendency to settle, frequent stirring is necessary during the painting operation. If the paint is too heavy for use, it shall be thinned with *such thinner as the manufacturer may specify for the particular paint used. (No gasoline or benzene shall be used.)*

5. Application

The number of coats, color and kind of paint shall be specified by the customer. The first coat of paint shall be applied to the cleaned and perfectly dry surface before rusting begins. Additional coats shall be applied only under favorable conditions. All paint shall be applied by skilled painters and shall be carefully brushed out to a thin uniform coating, working carefully around rivet heads, joints and other irregularities in the surface. Each coat shall be allowed to dry thoroughly before the next coat is applied. Paint shall be applied only when the air temperature is at or above 40° F. It shall not be applied during wet or foggy weather or upon damp surfaces or upon metals containing frost.

DISCHARGE BY SPRINKLER HEADS

No. of Sprinklers	Pressure in Lbs. per Square Inch at Sprinkler						
	5	10	15	20	25	30	35
1	14.	18.	22.	25.	28.	31.	33.
2	27.	36.	43.	49.	55.	61.	66.
3	41.	54.	65.	74.	83.	92.	100.
4	54.	72.	86.	99.	110.	123.	133.
5	68.	91.	108.	124.	138.	154.	166.
6	82.	109.	130.	148.	165.	184.	199.
7	95.	127.	151.	173.	193.	215.	232.
8	109.	145.	173.	198.	220.	246.	266.
9	122.	163.	194.	222.	248.	276.	299.
10	136.	181.	216.	247.	275.	307.	332.
20	272.	362.	432.	494.	550.	614.	664.
30	408.	543.	648.	741.	825.	921.	996.
40	544.	724.	864.	988.	1,100.	1,228.	1,328.
50	680.	905.	1,080.	1,235.	1,375.	1,535.	1,660.
60	816.	1,086.	1,296.	1,482.	1,650.	1,842.	1,992.
70	952.	1,267.	1,512.	1,729.	1,925.	2,149.	2,324.
80	1,088.	1,448.	1,728.	1,976.	2,200.	2,456.	2,656.
90	1,224.	1,629.	1,944.	2,223.	2,475.	2,763.	2,988.
100	1,360.	1,810.	2,160.	2,470.	2,750.	3,070.	3,320.
200	2,720.	3,620.	4,320.	4,940.	5,500.	6,140.	6,640.
300	4,080.	5,430	6,480.	7,410.	8,250.	9,210.	9,960.
400	5,440	7,240.	8,640.	9,880.	11,000.	12,280.	13,280.
500	6,800.	9,050.	10,800.	12,350.	13,750.	15,350.	16,600.
1000	13,600.	18,100.	21,600	24,700.	27,500.	30,700.	33,200.
2000	27,200.	36,200.	43,200.	49,400.	55,000.	61,400.	66,400.
3000	40,800.	54,300.	64,800.	74,100.	82,500.	92,100.	99,600.
4000	54,400.	72,400.	86,400.	98,800.	110,000.	122,800.	132,800.
5000	68,000.	90,500.	108,000.	123,500.	137,500.	153,500.	166,000.

PREPARATION OF METALS FOR PAINTING*

By R. E. Gwyther

Technical Service Dept., Sherwin-Williams Co., Cleveland, O.

PAINT is widely used and very effective means of protecting metals from atmospheric corrosion. Paint protects metals in two ways: by separating the metal from its corrosive environment (such protection is not perfect because paints known today are not completely impervious to moisture and oxygen), and by the use of inhibitive pigments, which provide protection when the paint is penetrated by corrosive elements.

Despite this dual nature of paint protection, even the best of paints, if applied to an improperly prepared surface, may fail to give the desired degree of protection. Too, some corrosion problems cannot be met by paint alone.

Metals Must Be Clean

In practice, metals are covered with films of materials such as corrosion products, mill scale, rustproofing oils, surfacing compounds, dirt, grease, etc. This layer can be wet by paint, but may itself lack adhesion to the metal. Small quantities of oil and grease and even fingerprints, will prevent adhesion between the paint and the metal. Paint which does not have good bond to the metal tends to blister when exposed to moisture. Blistering is aggravated by the osmotic effect of water soluble materials present on the metal surface. It is true that some surface products, such as thin, tightly adherent scale are not objectionable and may even be a good base for paints. In general, however, all foreign materials must be removed from the surface of the metal before painting. After cleaning, a metal can be quickly tested for cleanliness by simply rinsing with cold water. If the metal surface supports a continuous water film, it is considered reasonably free from oils, greases and insoluble soils. The test is occasionally obscured by the presence of hydrophilic wetting agents, which may permit a break-free water film even when grease is present. Rinsing before the cleaning will detect the presence of such an agent.

Simple Cleaning Methods

There are several methods for cleaning sheet or other smooth metal surfaces. A widely used but undependable method is to wipe the metal with rags soaked with petroleum or aromatic solvents. Unless considerable quantities of clean cloths are used, much of the grease is not removed, but smeared over the entire surface. Spray application of the solvent is more effective; the fire hazard is bad, but probably no worse than that of large quantities of solvent-soaked rags.

For test panel cleaning, a mixture of naphtha and xylol has been used as a spray solvent with considerable success. The procedure is to spray the solvert with an ordinary paint spray gun, with atomization jets nearly closed, from an acute angle, just as you would clean dirt and leaves from a sidewalk with a garden hose.

An important application of solvent cleaning is vapor degreasing, using the non-inflammable solvents, trichloroethylene or perchloroethylene. For stubborn soils, immersion or spraying methods may be used, the final cleaning in any case being in the vapor phase. The metal is hung in vapors of the boiling solvent. Clean solvent condenses on the metal so long as the metal temperature is below the dew point of the vapor. At equilibrium temperature, the metal is removed from the vapor dry. Chlorinated solvents must be stabilized to prevent dissociation, under certain conditions forming products which stimulate corrosion.

Alkaline cleaners consist of alkaline salts plus soaps, detergents, clays, etc., usually sold under proprietary brands. They are used in hot, dilute aqueous solution, by immersion or by spraying. Animal and vegetable oils are removed by saponification, and mineral oils and insoluble matter by emulsification or colloidal action. Highly caustic cleaners should be used for ferrous metals only.

Alkaline cleaners are low cost and very effective cleaners. Efficiency can be increased by application of electric current, making the object the cathode. Alkaline cleaning must be followed by very careful rinsing, because any alkaline residue will react with saponifiable portions of the paint, destroying paint adhesion.

Emulsifiable cleaners contain grease solvents plus soaps and detergents to give better emulsification and rinsing qualities. This concentrate is mixed with kerosene for use. It is sprayed, dipped or brushed on the metal and allowed to stand until it penetrates the soil. Then they may be rinsed off with water. A milky emulsion is formed during the rinse. The chief advantage of emulsion cleaners is flexibility of use.

In removing corrosion and scale from heavy metal by scraping, wire brushing or sanding by hand, results are limited and depend on the care of the operator. Powered processes such as wheel or belt grinding or rotary wire brush are more effective. A roughly sanded surface is known to be of irregular activity and subject to corrosion; this is not true of prolonged fine sanding. Blasting with sand, shot or grit produces a chemically clean surface. A blasted surface must be painted before corrosion occurs.

Flame cleaning is used to remove scale by extremely rapid heating, followed by rapid cooling. Differences in expansion cause the scale to break away from the underlying metal. Flame cleaning is also used to remove condensed moisture from structural steel prior to painting.

Chemical Treatments for Iron and Steel

Rust removal is of primary importance in painting iron and steel. Paint applied over rust will usually blister when exposed to moisture, because moisture causes rust to swell. Corrosion once started under a paint film spreads rapidly.

Phosphate treatments are the most successful treatments for iron and steel prior to painting.[1] The phosphate solution consists of an aqueous solution of phosphoric acid saturated with phosphates of the metals (iron, manganese, zinc or cadmium) plus an accelerator. Iron or steel immersed in the solution at near boiling temperature from one to five minutes is coated with metal phosphates, which are crystalline and chemically united with the metal surface. Phosphate coatings are insoluble, passive to corrosive reactions, abrasion resistant, and adherent. They provide an excellent base for paints and prevent spread of corrosion under the paint film.

A typical production sequence for phosphating follows:

(1) Alkaline clean
(2) Rinse

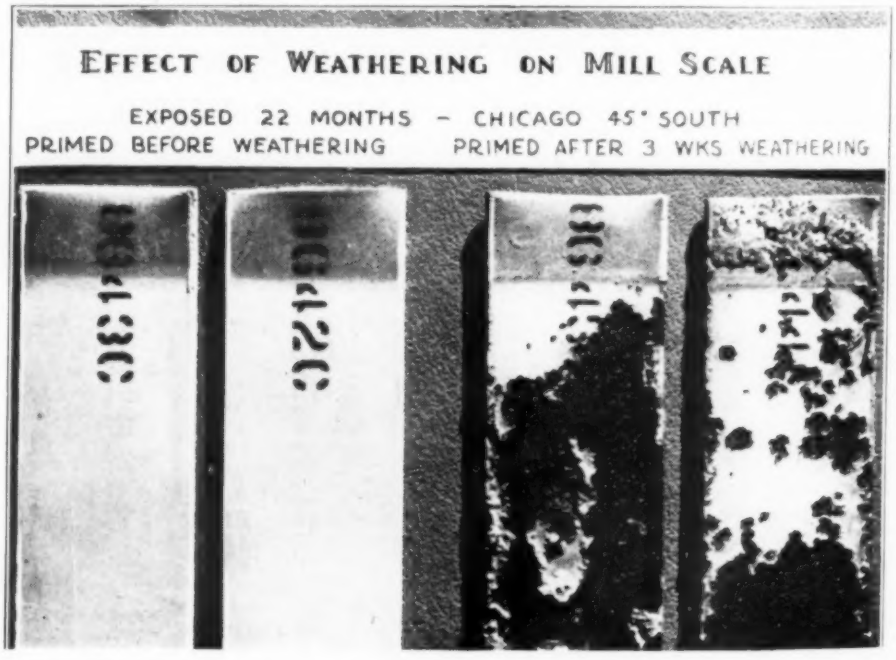

EFFECT OF WEATHERING ON MILL SCALE
EXPOSED 22 MONTHS - CHICAGO 45° SOUTH
PRIMED BEFORE WEATHERING
PRIMED AFTER 3 WKS WEATHERING

Fig. 1.—Illustrating the effect of weathering on mill scale. Panels at right were exposed three weeks, then wire-brushed to remove loose scale prior to painting. Panels at left were painted before exposure. The entire groups of panels were given one coat of synthetic zinc chromate primer and a coat of synthetic paint and then exposed 22 months at the Sherwin-Williams laboratory in Chicago. Panels at left remained in excellent condition while panels at right were failures due to the effect of corrosion products remaining on the surfaces before painting.

*From *Corrosion*, April, 1947. Reprinted by permission of the Nat. Assn. of Corrosion Engrs.

(3) Rinse
(4) Hot phosphate dip or spray
(5) Rinse
(6) Dilute chromic acid rinse

Phosphoric acid cleaners consist of phosphoric acid plus grease solvents (such as alcohols), and other ingredients. When applied in a process similar to that described above, they produce an amorphous coating at lower cost, but with less corrosion protection than the phosphate method.

An amorphous coating permits better paint gloss than the crystalline coating. Phosphoric acid cleaners are also used for simpler methods of application, such as the brush-on, wipe-off method, which combines cleaning and passivation in one operation. Protection afforded by these cleaners is variable, depending on constituents. In any case they accomplish removal of rust.

Phosphoric acid cleaning in general should be followed by rinsing. Gelatinous residues in particular must be removed before painting. Chromic acid in very dilute solution is used as a final rinse after phosphating. The acid rinse insures that the metal is not left alkaline from industrial rinse waters, which would preclude good paint adhesion. Chromic acid rinse, as a single treatment set down as follows, has been found to have considerable passivating effect on iron and steel:

(1) Alkaline or emulsion clean.
(2) (3) Rinse cold and hot.
(4) Rinse in hot dilute chromic acid, or in some cases dilute chromic and phosphoric acids.

We have found that for maximum resistance to blistering in humidity or water immersion, complete removal of salts and other water soluble materials from the metal surface is required; for maximum salt spray resistance, it is important to use a chromic acid rinse, leaving the metal in slightly acid condition.

Preparing Structural Steel

The most pertinent characteristic of structural steel is the presence of hot rolling scale. The scale is comparatively brittle and will crack and flake under stress, particularly if heavy. Rust tends to form at crevices and spread between the scale and the metal.

The best treatment for scale is to remove it entirely by pickling or blasting, followed immediately by chemical treatment, or a coat of primer. Scale removal is not widely practiced owing to cost and production difficulties. It is, however, in use in some cases where particularly severe corrosion conditions must be met. If not removed completely mill scale is better not removed at all. Loose scale, of course, must be removed in any case. The worst possible way to remove scale is first to loosen it by weathering. Unfortunately, this method is rather widely practiced.

Hot phosphate treatments are excellent for structural steel, but the process can be used only prior to erection of a structure. Phosphoric acid cleaners are used successfully for cleaning ship hulls, storage tanks and other relatively smooth surfaces. If used for structural framework containing joints, crevices, etc., in which the acid can collect, excess phosphoric acid must be removed from crevices or from under loose edges of scale. If not removed, the resulting damage to the paint film will more than offset the value of the treatment.

How to Prepare Zinc

Paint adheres poorly to new zinc, possibly due both to the extremely smooth surface and to chemical reaction between the metal and the paint. This is sometimes called "alkaline peeling," on the theory that the metal hydroxide formed in the presence of water reacts with paint acids. It has been proved that reaction occurs between the metal and paint vehicle decomposition products.[2]

It is not solely the burden of chemical treatments of the metal to prevent this reaction. The use of alkaline pigments and zinc dust in primers is well established. Reaction with paint decomposition products is thus distributed through the paint film rather than being concentrated at the metal-paint interface, where greatest damage to paint adhesion will result.

Weathering, mechanical roughening, and simple etching of zinc surfaces improves paint adhesion, but contributes no protection against corrosion. The best chemical treatment for zinc and galvanized iron surfaces is the phosphate treatment as recommended for steel. Phosphoric acid cleaners are also used; these remove existing corrosion, improve paint adhesion, and give some corrosion protection.

Chromate and dichromate treatments as a class produce a passive surface as indicated by salt spray tests, but usually fall down on long exterior exposure tests. This may be due to the solubility of the coating, or inability of the coating to prevent reaction between paint and metal. These coatings consist of zinc oxide, zinc chromate and some may contain chromium oxides or hydrates. Passivation has been claimed due to slow release of hexavalent chromium to water. Zinc-coated sheet steel is marketed under various trade names, with surfaces chemically treated, usually with a phosphate treatment, to provide a better paint base. In painting over these metals usually excellent exposure results are obtained.

Preparation of Aluminum

Due to the formation of a protective impervious oxide, aluminum is naturally resistant to corrosion. Pure aluminum is soft, and for many uses must be alloyed with small amounts of other elements, chiefly copper, manganese, silicon, and zinc. Much of the need for chemical treatment arises from the corrosive influence of the alloying metals. However, except for exposure to salt water, aluminum presents no great painting problem. Three types of simple chemical treatment are used prior to painting:

Alkaline dichromate treatment: The metal is alkaline cleaned, then immersed in dilute sodium carbonate-sodium dichromate solution at near boiling temperature. The coating is then sealed by immersion in hot dilute dichromate solution.

Chromic acid treatment: The metal is cleaned, then immersed in dilute chromic acid at 120-140° F.

Phosphoric acid: This is usually phosphoric acid in solvents such as alcohols, applied by dipping or by swabbing.

The alkaline dichromate method produces the heaviest and best coating of these simple chemical treatments. These treatments are not suitable as protective coatings alone, but provide excellent surfaces for painting.

Anodizing, on the other hand, produces a coating which has considerable corrosion resistance without painting. The metal is alkaline cleaned, then immersed 30 minutes in dilute sulfuric or chromic acid. The metal is made the anode and the tank the cathode. Voltage, current density, temperature and the solution are regulated to produce the desired coating. The film, essentially Al_2O_3, is initially porous, but is sealed by boiling 30 minutes in water or dichromate solution, converting the oxide to a hydrate.

Anodic coatings have considerable corrosion resistance. They are good surfaces for painting but need not be painted except when unusual protection is necessary. If the coating becomes soiled, the use of strong acid or alkaline cleaners before painting will damage the film. Anodizing is relatively costly, thus should not be considered as a quick metal preparation for painting, but rather as a high-quality coating for superior corrosion resistance, especially for resistance to salt water.

Normal atmospheres have little effect on magnesium other than discoloration. In salt water, the protective oxide coating is penetrated by the chloride ion, and corrosion is more rapid. The corrosion product is bulky, unsightly and non-adherent. Paint applied to magnesium is subject to "alkaline peeling," similar to that experienced with zinc.

Most magnesium products are finished with a protective chemical coating even before final fabrication of the product. This coating is intended to protect the metal during storage, shipment and manufacture. The chrome pickle process, known as Dow No. 1 or AMC "A," is used for this purpose. The treatment comprises a short immersion in a solution of nitric acid and sodium dichromate. The coating is suitable as a paint base, but cannot be used where close tolerances are required, due to etching of the metal. The dichromate process, known as Dow No. 7 or AMC "G," is the best process for corrosion resistance and is the most widely used as a base for painting. The process is as follows:

(1) Solvent vapor or emulsion cleaning
(2) Alkaline cleaning
(3) Immerse in HF solution (10-25 per cent)
(4) Cold water rinse
(5) Immerse 45 minutes in dilute sodium dichromate
(6) Rinse cold and hot.

Magnesium can also be anodized, producing a coating which has excellent corrosion resistance. Probably the best known method is the Navy PT-13d Process.

Conclusions

The following points are noted in the conclusion:

(1) Metals should be cleaned thoroughly to remove soils and corrosion products before painting.

(2) Requirements for a good chemical coating as a base for paints are: Insolubility, adherence to metal, and ability to prevent reaction between paint and metal.

(3) Careful rinsing after any chemical treatment is essential for maximum moisture and humidity resistance.

(4) Painting should be done as soon as possible after surface preparation.

(5) Simple chemical treatments are not of adequate protective value in themselves, but used as a step in a coordinated finishing program are of utmost value in extending paint life.

References

[1]Pollard and Porter. National Bureau of Standards Report, BMS-44, 1940.

[2]H. J. Wing. *Ind. & Eng. Chem.*, 28, 242, 1946.

BUILDERS-PROVIDENCE, INC.

(DIVISION OF BUILDERS IRON FOUNDRY)

36 CODDING STREET . PROVIDENCE 1, R. I.

District Offices in Chicago, New York, Pittsburgh and San Francisco
Representatives in principal cities of U. S. A. and Canada

BUILDERS WATER AND SEWAGE WORKS Equipment

Differential Producers • Flo-Watch
Type M Register-Indicator-Recorder
Filter Controllers Model RCE, Model RCA & RCB
Filter Gauges, Rate of Flow—Loss of Head—
Liquid Level—Sand Expansion • Large Dial Gauges
Ratio Indicating Gauges • Filter Operating
Tables • Wheeler Bottoms • Flo-Gage
Conveyoflo Automatic Conveyor Scales • Manometers
Meters for Open Flow • Chronoflo Telemeters
Propeloflo Meters • Auxiliary Equipment

VENTURI METER

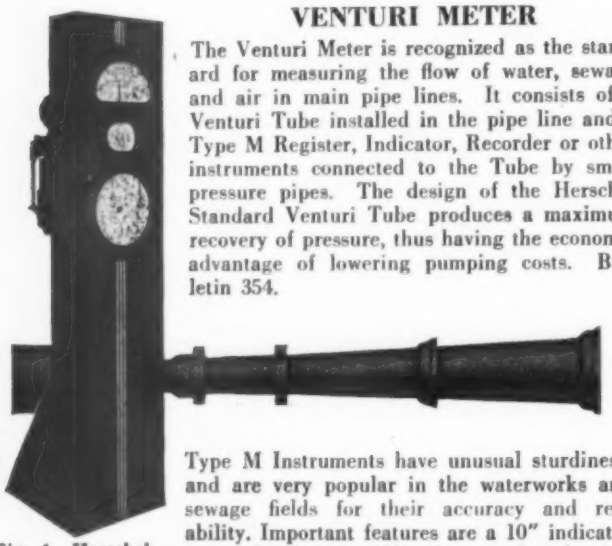


Fig. 1. Herschel Standard Venturi Tube and Type M Register - Indicator-Recorder

The Venturi Meter is recognized as the standard for measuring the flow of water, sewage and air in main pipe lines. It consists of a Venturi Tube installed in the pipe line and a Type M Register, Indicator, Recorder or other instruments connected to the Tube by small pressure pipes. The design of the Herschel Standard Venturi Tube produces a maximum recovery of pressure, thus having the economic advantage of lowering pumping costs. Bulletin 354.

Type M Instruments have unusual sturdiness, and are very popular in the waterworks and sewage fields for their accuracy and reliability. Important features are a 10" indicator at eye level with uniformly spaced scale; improved integrator; 12" uniformly spaced charts; white pyralin dials and interior illumination. This instrument furnishes three kinds of information: continuous indication of the flow; a permament record on the 12" chart; and the total quantity on a 3½" counter dial. All dials graduated in direct reading units for the particular line being metered. Bulletin 324A.

PROPELOFLO METER

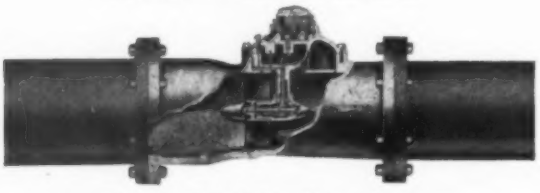


Fig. 2. Propeloflo Meter flange mounted. Available also in bell and spigot model.

This improved, propeller-type flow meter for main water line metering introduces many new features including streamline Venturi design. A self-contained unit easily installed; registers total flow directly in gallons. Accurate throughout wide range; low loss of head; low first cost and upkeep. Bulletin 350A.

FLO-WATCH

A small, medium-priced mechanical instrument which measures the flow of liquids, steam, air and gas through standard differential producers such as Venturi Tubes, Nozzles and Orifice Plates. Also furnished with Kennison Open Flow Nozzles, Parshall Flumes and Weirs or for open channel flow measurement. This sturdy, accurate and dependable instrument is available in a variety of mountings and dial combinations and for remote operation of secondary instruments or the automatic proportional control of dry or liquid chemical feeders. Three separate easy to read dials are compactly arranged in the space usually required for only two dials:

(1) Fast moving, seven-digit cyclometer type Totalizer.
(2) Uniformly spaced 10-inch segmental Indicator.
(3) Uniformly graduated 12-inch Chart Recorder. Bulletin 318B.

FILTER CONTROLLERS

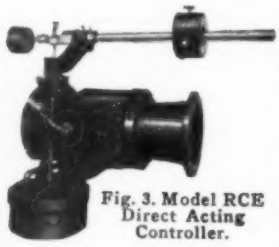


Fig. 3. Model RCE Direct Acting Controller.

Several models are offered, each designed for particular conditions, to automatically maintain constant flow rate through the filter bed. Model RCE features smooth, unwavering control; low loss of head; sturdy, balanced valve; compact flexible design; powerful "floating piston" and exclusive molded tapered piston seal. All rotating bearings anti-friction. Modified for higher pressures and velocities, these controllers serve as Wash Water Controllers or in the effluent lines from pressure filters. Bulletin 321A. Models RCA and RCB are hydraulically operated. Model RCA has a gate type valve with specially shaped seat. Model RCB has a special double butterfly valve of rectangular section and is used for lines over 12" diameter. Bulletin 325A.

FILTER GAUGES

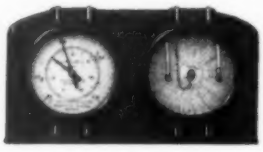


Fig. 4. Loss of Head and Rate of Flow Gauge.

Filter Gauges are usually mounted on the operating table convenient to valve controls, but can be mounted on self-supporting floor stands where desirable. The indicator and chart display accurate information gathered by the dependable Builders Diaphragm Pendulum Units. Attractively designed for modern plant interiors. Available in many combinations to indicate and/or record Rate of Flow, Loss of Head, Liquid Level and Sand Expansion. Special types are custom built to engineers' specifications. Bulletin 329A.

METERS FOR OPEN FLOW

Flow through partially filled pipes, sewers and open channels, using a Kennison Nozzle, Parshall Flume, or Weir, where there is a wide range of flow rates, can be accurately measured using standard Builders instruments. The Kennison Nozzle is particularly successful in measurement of raw sewage sludge and trade waste. It is available in sizes from 6" to 36". Bulletins 334A (Kennison Nozzles) and D-2-100.21 (Parshall Flume).

CHRONOFLO TELEMETERS

Fig. 5. Chronoflo Receiver.

Chronoflo Telemeters bring to a central operating point, from widely scattered locations, accurate records of flow, level, pressure, temperature, gate position and weight. Chronoflo Transmitters are electrically connected by a simple two-wire circuit to Chronoflo Receiving Instruments. Automatic proportional control of Chemical Feeders in step with rate of flow is accomplished by a simple attachment to a standard Chronoflo Transmitter. Bulletin 320B.

METERING: PRACTICAL METHODS OF PROCEDURE*

By E. H. RUEHL†
Richmond, Va.

"TO METER or not to meter?" That is the question. Those who have gone through the problem of making initial installation of water meters know what significance these few words can have and what discussions can be caused thereby.

However, metered water service is being acknowledged more and more as being the best all-round method of distributing the indispensable commodity, water. This is especially true since the unprecedented drought of 1930, and I am sure that if more communities were metered at that time the effects of the drought would have been less severe due to the lessened wastage of water.

Why Services Should Be Meteerd

There are many good reasons why water services should be metered, a few of which are:

1. It is the fairest way of selling water, as all customers pay in proportion to their respective consumptions.

2. The water department or company has a pretty good check on the amount of water sold and by comparison with readings of a master meter can better establish losses and leakage and thereby reduce waste in the system in general.

3. Leaks in consumers' service lines can better be located.

4. Knowledge of the various water consumptions is essential in establishing equitable water rates, and the only way in which this information can be obtained and analyzed is by metering of all services.

In some cases, especially in the municipally owned plants, there are certain institutions, such as schools, hospitals and the like, that are supplied with water without charge, and these should be metered and read regularly to get the full benefits of 100 per cent metering.

And here let me digress a little to state that the words "municipally owned" are generally a misnomer, as in the majority of cases the municipality has a large obligation in the form of outstanding bonds, and the only part that is really municipally owned is the amount covered by bonds purchased back, or some such similar item. This is mentioned here because in the municipally operated plants we are so often confronted with the statement that the people own the plant and for this reason they should have all the water wanted for some flat rate that is nowhere commensurate with the cost of producing the water, the fixed charges being lost sight of entirely.

5. It has been proven that as meters are installed that consumers' wastes have been reduced and this in turn effects economies in the amount of power required to pump, if it be a pumping plant, and in treatment costs, which are getting higher and higher every day.

6. As the water requirements of the city are kept within bounds and more or less controlled, the size of the treating and pumping plants and storage and distribution systems are kept to a minimum, thereby keeping capital investment to a minimum, as well as the necessary interest and sinking fund charges, which all result in keeping of the water rates at the lowest possible figure.

7. As the time has come when sewage treatment will become necessary in a good many places, the lowering of the water losses and wastes will redound to the town's advantage in requiring a plant of smaller capacity than would be necessary if water usage and wastage were uncontrolled. Likewise, sewage pumping costs will be less.

With all these reasons in favor of metering, the only ones against it are generally found to be caused by the selfish motives wherein certain customers may want to use unlimited quantities of water without paying a just price therefor. This can be overcome in a great many cases by explanation, and, in spite of the fact that many may be adamant at first, good results are usually obtained.

Another argument against metering is sometimes set forth in that it is claimed that sanitary conditions will not be maintained if water usage be curtailed due to the installation of meters, but it has been shown that for all purposes about 25 gallons per capita per day is all that is absolutely necessary. Under any ordinary rate the cost for this requirement for the average family for an entire month would be modest, in most cases less than the cost of one filling of the gasoline tank of the automobile.

It can therefore be seen that metering is beneficial to both the municipal plant or privately owned company as well as to the consumer, since it contributes a means of compiling equitable rates and keeping bills to a minimum.

Ownership and Location of Meters

Since the type of meter and location of meter setting is governed to some extent by geographical location and local conditions, the remarks that are to follow must of necessity be confined more or less to a particular section and will apply to Virginia.

The ownership and location of the water meter are two subjects on which divergence of opinion exists. In the writer's opinion, the meter should be owned by the water department or company (being charged to capital account) and all maintenance should be done by the owners and charged to operating costs. In Virginia the meter setting just inside the curb line offers so many advantages over other locations that these readily outweigh any disadvantages in the nature of a small additional installation cost, should this be the case. In a good many houses in this section of the country there are no basements in which to locate a meter.

Advantages of Outside Setting

The advantages of outside setting, located in the sidewalk space, are in general as follows:

1. Meter reading is greatly facilitated due to the fact that the reader never needs to wait for a response from the householder on knocking, and does not have to make a second trip if absence of the occupant prevents a reading on the first call. The distance the meter readers have to walk is lessened when outside settings are used, and this in turn permits more meters to be read per day.

2. The meter is always accessible to water department employees for reading, inspecting, testing and repairing.

3. The danger of the meter readers and other water department employees from attacks from vicious dogs is eliminated.

4. The chance of unauthorized persons entering the house in the guise of water works employees is greatly eliminated.

5. Chance of the meter being covered by rubbish, coal, kindling wood, etc., is done away with when the outside setting is used.

6. More accurate reading can be procured when outside settings are used because of better lighting outside than generally exists in basements, under porches or other places where meters might be set.

7. The line of separation between the water department and property owners' liability is clearly defined and there is not much chance of unauthorized connections being made behind the meter.

8. In case of necessity of cutting off the water for non-payment of bills there can be no dispute as to entering the premises if the meter and control are located at the curb line.

9. The outside setting should be in a locked box. As it is below the ground, it is not so apt to be tampered with as would a setting in a more conspicuous place not protected by a box.

10. Less danger of damage to the meter by hot water exists if set at the curb.

11. Danger from freezing is practically eliminated in a well set meter, and in case of fire in the building supplied the meter is not in danger of being destroyed.

In view of all these reasons the writer is of the opinion that the entire meter setting, including the necessary cut-off valve, should be located in the sidewalk space behind the curb line, and that the water department's or company's maintenance and obligations should stop at the customer's side of the meter.

Type of Setting

The following remarks apply to the smaller size meter up to 1-inch, and when larger sizes than this are used the condition must be studied separately and settings made to suit.

It is realized that a properly set meter, although not always the cheapest, will receive more attention in general from the

†Former City Manager, Bluefield, Va.; now with Stuart Royer & Assoc., Engrs., Richmond, Va.

water works operatives and in turn pay higher returns to the department.

It is a good plan to set the meter in a yoke with at least a control valve at the inlet side, although some prefer valves at both the inlet and outlet sides. This does away with the customary curb stop and box.

The meter in its yoke, and with the control valve, should be set in an earthenware, concrete or iron box with sufficient clearance between the risers, if they be used, that the cold ground outside cannot cause the water in the pipes or meter to freeze. A type of box that has proven very satisfactory in our section of the country is one 18 inches in diameter and 24 inches deep, with side slots at the lower end to accommodate the varying depths of the service pipe. The latter, we feel, should be about 24 inches below the ground.

It is important that a lid be provided that fits the top of the box tightly, preferably being locked on with some kind of a locking device. If the lid is fastened on there will be no circulation of air in the box and consequently less danger from freezing. Another advantage is that if the lid is kept on tightly there is less danger of persons tampering with the meter or of pedestrians catching their feet in the hole, with a possible damage suit resulting.

It is also very important that the bottom of the box extend below the maximum frost line so that the warm air from below can rise up around the meter and risers and keep the atmosphere in the box above freezing. In extreme cases it has been found that a smaller tile pipe about 8 inches in diameter put vertically into the ground below the bottom of the regular box (to reach warmer levels) overcame freezing troubles by admitting warmth from below.

Meter Reading

In the writer's opinion, meters should be read monthly, if this is possible, as by so doing a closer touch is kept on losses and wastes, and due to the visiting of each meter every thirty days the stopped meter and other irregularities can be more effectively dealt with. In case a customer has a leak he can be notified within a reasonable time if the meters are read monthly, but if they are read, say, quarterly, the amount of leakage passed will more likely be an appreciable amount and cause some disagreeableness when an attempt is made to collect the bill.

Experiences at Bluefield, Virginia

If you will pardon personal experiences, it may be of some interest to tell how the town of Bluefield recently attacked the problem of setting 700 meters at the rate of something like 100 per week. This was carried on as follows:

A work sketch was first made up and the various kinds of equipment decided on. After the meters, yokes, boxes and covers were ordered out, some figures were made up giving the length of pipe to be cut from the service to allow for elbows, yoke, valve, etc., and the vertical distance that cover, meter, yoke and fittings required was figured and each made into a constant.

Actual installation started with several men digging holes, located from the curb boxes whenever possible, in a certain well defined section so that one foreman could keep all things going. Two men, both of whom had some previous pipe fitting experience, were formed into a "gang" and given instructions how to set the meters, and they then worked together for about a day. These men then were given a helper each and two setting "gangs" were formed and these two helpers were in turn given helpers and four setting "gangs" were formed in a few days. The work was carried through, with as many men as were necessary to prepare the holes ahead of them.

Tools Required

Each of these setting gangs of two men each was furnished with a ratchet die holder and one-half and three-quarter inch dies, a hack saw, two 10-inch Stillson wrenches, a pipe vise attached to a four-legged board, a home-made wooden straightedge, and a pair of hip boots. The men provided their own rules. The meters, yokes, boxes, covers, pipe, etc., were supplied to the location by a Ford truck. Galvanized nipples of various lengths were purchased and used wherever possible, as they could be purchased cheaper than we could buy, cut and thread the pipe.

When the hole was opened down to the service pipe the meter-setting gang (two men) came along and the first thing they did was to lay the straight-edge across the hole and measure down to the service pipe, and from this the proper "constant," referred to above, was subtracted, which gave the length of risers necessary to bring the top of the meter to the desired point below the meter box lid. If there was a standard nipple of length somewhere near this dimension it was used. If not, the helper would cut pipe to the proper length and thread it. The meter setter in the meanwhile would be cutting a piece of pipe of predetermined length out of the service line and threading the cut ends for elbows. The risers were then screwed in and the yoke and meter set, after which the box was put in the hole. By using a set of specially made hooks the box was easily adjusted around the meter and risers, and the cover put on.

Two men constituted the back filling gang and followed up all setting gangs, backfilling all holes and seeing that the lids were properly fastened.

If the existing cut-off in the service line was so located that it could be used to control the water it was used, but if not the meter setter would cut and thread the pipe under pressure, which only took a very few minutes. He would screw the riser pipe with control valve on, bail out the hole, and go on without having to dig back to the main or cut the water off of a section of the town. The water lost amounted to very little.

One foreman looked after the entire job and 700 meters were set at the rate of about 100 per week.

The cost of this work complete, including tools, boots, and everything, was slightly under $19 per setting, which also included the changing of some services where it was necessary.

We believe that in a place where the services are fairly close together one foreman could handle about six meter setting gangs with the necessary hole diggers and could set about 150 meters per week, providing that everything is thoroughly planned ahead.

RENOVATING WATER METERS

Water companies, on the whole, and also several of the more progressive municipally owned water departments, have found that a little dressing up of overhauled meters before returning them to the customers' service has a desirable psychological effect on the customer. The spray gun and gilt or silver lacquer or a combination of the two is the usual method of dressing up old meters after they have been overhauled and tagged "O.K." on the test bench.

Mr. La Verne Trentlage, superintendent of meters in the water department of Elgin, Ill., has evolved a scheme which goes the spray-gilting method one better in making "new" meters out of old ones. In the Elgin scheme the metal parts of the meter are given a treatment which removes the oxidized or carbonated coating from the metal and leaves the parts as metal-bright as when turned out by the manufacturer.

Cleaning and Brightening Procedure

(1) Dip meter parts for 10 minutes in *hot* Trisodium Phosphate solution (2½ lbs. or more of T.S.P. in 10 gallons of water).

(2) Remove meter parts from T.S.P. solution and rinse in *hot* water to remove the alkali.

(3) Dip the parts in Muriatic Acid solution (1 part 18 degree Muriatic Acid to 2 parts of water). Allow to remain in this acid bath for approximately 15 minutes, or longer if necessary. Remove and rinse in hot water.

(4) To brighten to original lustre, immerse in the "bright-dip" solution (1 part 38 degree Nitric Acid, 1 part 66 degree Sulphuric Acid and 1 part water, plus a handful of common salt). Leave the parts in the bright dip for 5 to 10 seconds, the length of time depending on the composition of the metal and degree of brightness desired.

(5) Remove and rinse in *boiling* water to remove acid.

(6) To keep the parts from dulling on standing, a "stabilizing-dip" (especially prepared for this purpose) has been developed by General Chemical Company). After the rinse, the parts are dipped into this solution, removed and allowed to drain and dry.

Notes of Caution: Always add acids to water and *not* water to acids when making dilutions. This will preclude over-heating and spattering of the acid. Be careful to avoid splashing of the acid when dipping the meter parts. In case acid accidentally splashes on hands or face, wash at once in clean water to avoid an acid burn. Spattered acid is also hard on clothing and shoes. Rubber aprons and gloves are good protection.

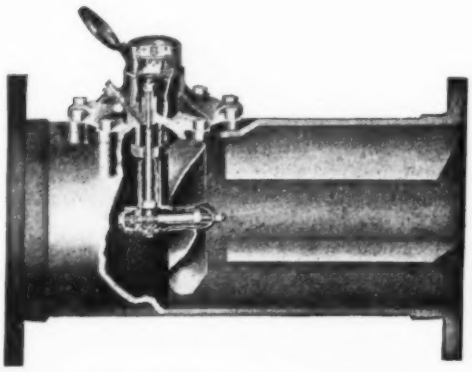
Do not use iron or steel wire for dipping meter parts. Copper or monel metal wire is satisfactory.

R. W. SPARLING

MANUFACTURER OF

MAIN-LINE WATER MEASURING EQUIPMENT

Box 3277, Terminal Annex, LOS ANGELES 54 — 3104 S. Michigan Avenue, CHICAGO 16
622 Broadway, CINCINNATI 2 — 101 Park Avenue, NEW YORK 17 — 6 Beacon Street, BOSTON 8



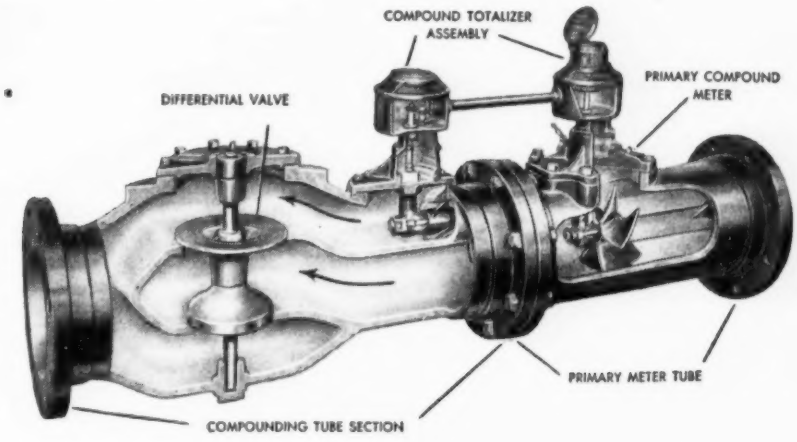
TOTALIZATION is the primary step in all Sparling Main Line Meters. Flow-rate indicators, recorders and controls are added as desired. Accuracy at rated ranges is guaranteed within 2 per cent, and loss of head is practically nothing!

FLANGED TUBES—2-inch to 36-inch
SCREW TUBES—2-inch to 6-inch
BELL & SPIGOT—4-inch to 36-inch
SADDLE-MOUNTED—6-inch to 72-inch

Note Direct Action from propeller to totalizer, which registers in quantity unit desired. Sparling Meters may be installed on suction or discharge side of pump, in horizontal or vertical position.

The meter may be saddle-mounted on the pipe or installed as a tube section as easily as a length of the pipe itself.

The entire outlay need not exceed $250 on a 6-inch main. Every Sparling Meter is backed by 27 years' experience.



Differential valve cracks at about one pound per square inch back pressure from the smaller meter. The smaller meter measures all flows below the minimum accurate range of the larger meter. Both meters drive through ratchet clutches to a common totalizer, which thus operates with the faster turning meter.

COMPOUND Meters for Mains up to 36-inch

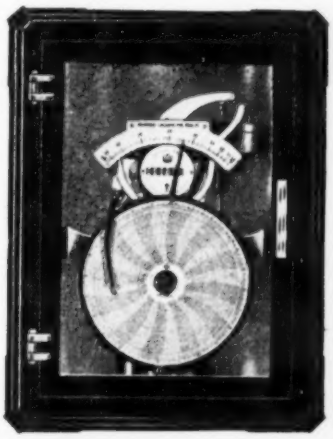
Consistent accuracy over flow-range as wide as 1-to-125.

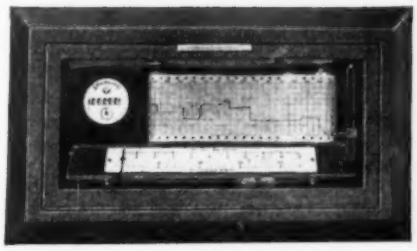
INDICATORS • RECORDERS CONTROLS

Flow-rate indicators and recorders are available for use with Sparling Meters if, as and when required. The mercury-governor type, with circular charts for 24-hour or 7-day records, are mechanically controled within 15 feet of the meter, or electrically controlled at any distance. They may be Pedestal, Wall or Panel mounted.

The differential type, shown at right, has a straight-reading 60-day strip roll chart. Indicator scale is calibrated in two flow equivalents. Operated by electric remote control.

Mechanical or electric controls for autometered sampling or chemical feed are available.





BULLETIN 309 COMES UPON REQUEST

WATER MAIN CLEANING

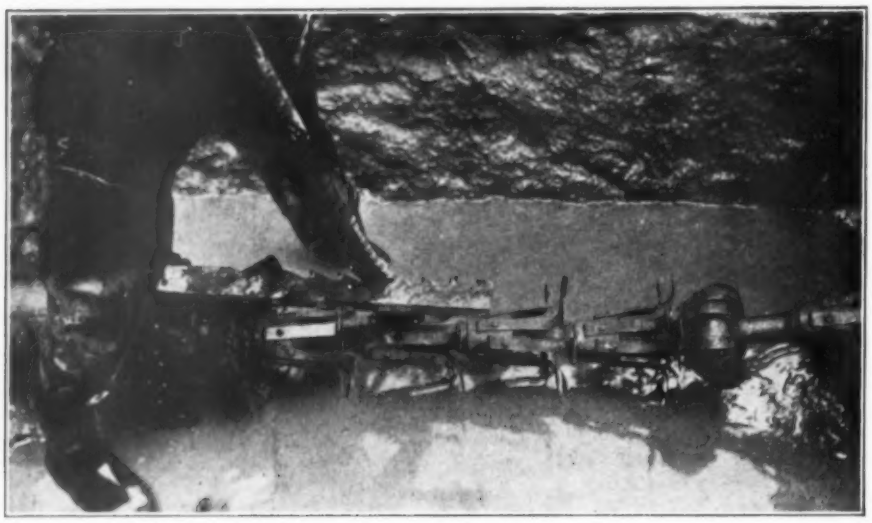
Some Recent Experiences and Results

By WM. S. STAUB, Engineer

West Virginia Water Service Co.
Charleston, West Virginia

AS A RESULT of main cleaning projects at three of our properties in this state, we have definitely raised the flows and pressures in those mains that have been cleaned and, in cases of the transmission mains, the pumping cost per million gallons has been reduced.

The purpose of this paper is to present our ideas of main cleaning, why we clean mains, what results we have had, the cost per foot to clean; to give a general description of the procedure and to observe what happens in a cleaned main.



"Jacking-In" Operation
About half of a cleaning tool jacked into an 8-in. main. It will travel under its own "steam" by main pressure turned in behind it.

In years gone by, when there was no water treatment or when the practice was in its infancy, beyond taste and appearance other characteristics of the water were given little thought. Therefore the distribution system suffered, due to lack of knowledge of corrective treatment. The deposition of the solids and the tuberculation reduced the area of the pipe and, therewith, the amount of water that would flow through the pipe under pressure available. Consequently, today, when there are complaints of poor pressure, or when increased fire flow is in demend, we are faced with the problem of main replacements or improvement of existing mains. Although the exterior of the pipe is usually as good, practically, as the day it was installed, the interior may present a scene comparable to the stalagmites and stalactites of the eastern caverns. If such choking deposits can effectively be removed from the pipe and the carrying capacity appreciably restored there will be great savings over replacements, even though the latter be necessary eventually..

A dirty main is definitely a liability. From the operating standpoint a dirty transmission main consumes many kilowatt hours of power due to the added friction. Kilowatt hours in turn cost money, which in turn increases operating expenses. A dirty main is a great handicap to the fire departments, due to insufficient quantities of water. Poor pressure complaints from consumers are not soothing melodies to a superintendent's ears. Consequently, everyone suffers from the effects of tuberculated pipes.

Locating the Trouble

When a main is suspected of being tuberculated. or when we find that the operating head on a pump is much greater than the static head plus the calculated friction head for new pipe, it is time to find the trouble. The distribution main is isolated in such a manner that all water going to a certain area must pass through the section of pipe to be tested. Then, in the early morning hours. the calibrated pressure gauges are placed along the line and a hydrant is opened at the end of the line. The amount of water is measured with a pitot-tube, the pressure drop is recorded and the loss per 1000′ or the value of "C" is determined. (For details of the method see "Hydrant Discharge Measurements," page 183. Reference and Data Number of Water Works and Sewerage, May, 1939.)

We admit this method of determining "C" is not as accurate as secured by Pitometer tests, but we feel that a reasonably accurate value is obtained if precautions are used. In the case of transmission mains, by determining the efficiency of the pumping equipment, static head, operating head, power consumed. water pumped, it is possible to get a very good check over any period. (For "A Simple Method for Checking Pump Efficiencies" see page 445, November, 1939, Water Works and Sewerage.)

Cleaning Procedure

The largest pipe which we cleaned was 10" cast iron. The 10" and 8" pipe was cleaned with the pressure cleaning machine, which uses the water pressure to push the device through the pipe. This machine (see pictures) is about 6′ long, composed of five cutting heads and two pistons. The heads are "vertebrae" upon which are attached, around the circumference, the cutting blades. The

The "Carrier"
A rod with leather piston cups is used to thread cable through 4-in. and 6-in. mains.

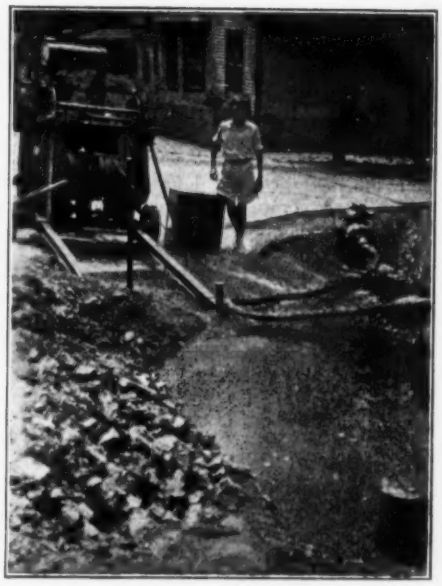
blades are of spring steel. There are two flexible "pistons" from which the machine gets its drive. There are adjustable ports through the pistons, which we can set to control the volume of water passing the machine for sweeping the debris ahead and, at the same time, to prevent the machine from moving too rapidly. Closing the ports naturally gives added driving power for the tougher jobs. The pistons and cutting heads are on a flexible spring and cable type of shaft. Its flexibility will allow the machine to pass a standard 90° bend. Contrary to the belief of many, the machine does not take on any spiral or whirling motion in its travel.

Cleaning 8 and 10 Inch Mains

The main is isolated and a section of pipe is removed at the point of beginning. This section should be long enough to give ample working room for inserting the machine. The machine is then jacked intothe pipe (see cut) and the pipe permanently jointed either by solid or Dresser sleeves. At that point at which we wish the machine to emerge the pipe is again cut. A short section is removed and bell and spigot fittings are used to rig a riser. Usually this is done with a 45° bend and a short piece of pipe. The joint need only be juted and chained. The purpose of the riser is to discharge the debris on top of the ground, rathre than in the trench. When the riser is rigged the pipe is all ready. The valve on the main is opened slowly to secure the proper amount of water and the machine begins to move. The machine generally moves about 100 feet per minute and it is possible to follow its travel through the line, as the water passing the pistons and the scraping blades is audible at the surface. Generally the water emerging from the riser will only be colored until the machine gets within about 300 feet, then the water is thick and black. The solid material may issue from the pipe like sausage, if the encrustation is marked. In the case of the 3900′ of 10″ line in South Charleston (W. Va.) there was an estimated one and one-half tons of solid materia! which came from the pipe. The machine will generally lodge in the riser pipe due to so much debris, and has to be helped out. When the machine has reached its destination (after only one trip through in most cases) the riser is dismantled, the main flushed, jointed, and placed in service.

Dollar Losing Debris

Some of the 1½ tons of solid material swept out of 3,976 ft. of 10-in. transmission main, to reduce pumping cost $2.37 per million. (See accompanying tables of data and costs.)



The Safety Winch

Pulling cleaning tool through a 4-in. line. In such operations the debris collects in the ditch, which is dewatered with the small portable pump alongside.

A Small Line "Make-Up"

In which the "carrier" with threading cable attached has been inserted in 4-in. main and is ready to travel.

Cleaning 4 and 6 Inch Mains

In the case of 6″ mains, where they are not so dirty, these may be cleaned by "pressure shots" as described for larger sizes of pipe. In one case where the pressure was low a booster pump was used to supply increased pressure for a 6″ "pressure shot." However, generally 6″ mains must be cleaned the same way as 4″ pipe, which I will now describe.

In cleaning 4″ mains the section to be cleaned is isolated and the main opened at both ends. At the beginning point a small cable is attached to a "carrier" and inserted into the line. The "carrier" is a short rod with leather pistons. The main is then jointed at this point with a portable coupling known as a "make-up." This "makeup" has a gland in the top through which the small cable may be fed. The water is then turned on behind and the water velocity takes the "carrier" and the small cable to the other end of the pipe. This small cable is then used to pull the big cable back to the point of machine insertion. The makeup is removed, the cleaning tool clamped to the large cable (see cut), the main permanently jointed, the water pressure turned on, and the cleaning tool is pulled through the pipe by a gasoline driven winch. This process is much slower than the pressure method and great care must be exercised to prevent breaking the cable and losing the machine. In this case a very slow speed is used. The winch automatically releases the clutch when the tension or pull becomes too great. This generally happens when the cleaning tool catches some joint lead or a bad obstruction. When the cleaning tool emerges the main is flushed and permanently jointed.

Obstacles Encountered

In pressure cleaning the drive of the machine is dependent upon the velocity of the water acting on the pistons, and in the event the machine encounters a cross increasing on the branches it will generally stop. In other words, in cleaning an 8″ pipe, if at an intersection an 8 x 10 inch cross is present the machine will hang. This is due to the pistons expanding and allowing the water to pass it instead of driving the machine.

If the wash water passing the machine is not sufficient to carry the debris ahead the machine will be fouled. We encountered one 8″ main in which the machine would move a short distance, then stop. After the wash water had moved the material ahead the

machine would move again. This happened on a long line where wash water was insufficient and blowoffs were too far apart. The machine had to re-run through this section and I am of the opinion that part of the debris was deposited behind the machine during the first cleaning.

Short radius bends with valves on one side caused several cuts to be made.

Insufficient pressure was a jinx on one job. We were cleaning a 10" main from the reservoir down the hill. The pressure at the point of beginning was only 17 pounds. Thus it was necessary to fill the line with water and bleed it rapidly at the bottom of the hill, thus creating a vacuum. When this was done it was then impossible to keep up with the machine.

Poor joints were responsible for a number of worries—poorly juted joints where the lead had run into the pipe. There were chunks of lead removed weighing 50-75 pounds, old pump gaskets, coil springs, timbers, rocks and, in one case a piece of 1½" pipe about 6 feet long. These had probably entered the system years ago when reservoirs were uncovered or when the pipe was laid.

An Ounce of Obstruction; A Pound of Cure

This section of 8-in. pipe didn't look "too bad," but results after cleaning showed that it was. Proof found in the accompanying tables of data, revealing the "before and after" story, is more convincing than many words about it.

Discoveries and By-Product Values

At Hinton practically the entire system was cleaned. As a result, the method in which tie-ins are made, the fittings, and location of mains were definitely established. I know that our superintendent there can now point out on the ground just what is at every intersection, because he made intersection cards accurately during the cleaning.

There were cases when a pipe which was supposed to be was not and vice versa. Old valves were found, some with box and all gone, some with stem broken and some found partly closed.

If anyone operating a water system, which has been in service for a number of years, attempts a job of main cleaning, he will probably be surprised at a great many things found. And, from the operating standpoint, the knowledge gained during cleaning of mains may well save a few nights sleep to the superintendent.

Conclusions

We feel that our main cleaning jobs have done a lot of good. Those who have seen the mains before and after know that flows have definitely been improved. Just how long this pipe will remain clean is another question, but we expect to keep a close check on the cleaned mains. In fact, we are taking daily samples at all points where we cleaned and are recording the pH, alkalinity and CO_2. Periodic flow tests will also be made to ascertain to what degree the main is tuberculating. We are trying to control our corrective-water treatments accordingly.

We do know that the fire flows have been greatly increased and that once weak hydrants are again gushing briskly. On transmission mains there have been definite and pleasing reductions in power consumed.

Costs and Cleaning Data

In the accompanying tables something of the data pertaining to cleaning operations and costs are presented for the benefit of those interested.

TABLE 1—Charleston Main Cleaning

Item	Pipe 6" Kanawha St.	Pipe 8" Va. St.	Pipe 10"** So. Chas.	Pipe 10"-8"** Nitro Line
Contract of Cleaning	$134.80	$271.70	$397.60	$1,488.95
Material Cost	6.19	48.86	138.29	250.40
Labor Cost	65.86	186.80	188.14	888.09
Total Cost	206.85	507.36	724.03	2,627.44
Number of Feet Cleaned	1348	2717	3976	29779
Cost per Foot	$ 0.1535	$ 0.187	$ 0.1823	$ 0.0882

* This cost does not include 8" temporary steel line which was laid. The rental of pipe, placing and removing cost $1,757.75 for 4200'. If this were added to the above the cost per foot for cleaning the 10" main would be $0.625.
** The 10" and 8" main is a transmission main and was cleaned as one unit. Therefore there was no breakdown in cost.

TABLE 2—Charleston Main Cleaning (Transmission Main)

Location	Size	Feet of Pipe Cleaned	"C" Before Cleaning	"C" After Cleaning
South Charleston	10"	3,976	66	130*
Nitro-Dunbar	10"	10,679	49	130
Nitro-Dunbar	8"	19,100	49	126
Charleston-Virginia St.	8"	2,717	—	138
Charleston-Kanawha St.	6"	1,348	—	115

* Yielding an estimated savings in pumping cost (power) of $2.37 per M.G. for the South Charleston main.

TABLE 3—Hinton Main Cleaning (Total Cleaning Costs)

Item	10" C.I.	8" C.I.	6" C.I.	4" C.I.
Contract of Cleaning	$177.40	$ 546.90	$255.60	$ 675.80
Labor Costs	42.92	238.33	185.60	376.86
Material Costs	44.25	245.54	189.30	301.96
Total Cleaning Cost	264.57	1,030.77	630.50	1,354.62
Cost per Foot	0.15	0.189	0.246	0.20

TABLE 4—Hinton Main Cleaning

Pipe Size	Ft. of Pipe Cleaned	No. of "Shots"	Max. Length "Shot"	Min. Length "Shot"	Ave. Length "Shot"	"C" Before Cleaning	"C" After Cleaning
10"	1,774	1	1,774'	1,774'	1,774'	—	128
8"	5,468	9	1,072'	215'	608'	48	126
6"	2,556	7	675'	189'	365'	80	117
4"	6,758	14	965'	36'	482'	44	122

TABLE 5—Sutton Main Cleaning

Item	Pipe 6" Main St.	Pipe 4" Town Hill	Pipe 4" South Side
Contract of Cleaning	$177.00	$325.40	$487.50
Material Cost	18.55	72.60	105.60
Labor Cost	90.50	166.40	249.20
Total Cost	285.85	564.40	842.30
Number of Feet Cleaned	1770	3254	4875
Cost per Foot	$ 0.161	$ 0.173	$ 0.172

TABLE 6—Sutton Main Cleaning

Location	Size	Ft. Pipe Cleaned	"C" Before Cleaning	"C" After Cleaning
Main Street	6"	1,770	42	136
Town Hill	4"	3,254	68	118
South Side	4"	4,875	71	117

MAIN CLEANING WITH COMPRESSED AIR

Compressed Air Also Used for Removal of Sand From Wells

By ROSCOE R. HOWARD

Superintendent Municipal Utilities, Slater, Mo.

HERE in Slater, Mo., we have two miles of 8-in. cast-iron pipe in the main which delivers water from the two deep wells, located near the shore line of the Missouri River, and the Water Purification Plant. From the purification plant a 12-in. main seven miles long delivers the filtered water into the city.

Every year the 8-in. main between the wells and the purification plant loses some of its carrying capacity because of the annular ring consisting of silt, iron, etc., which builds up on the interior walls of the main. This deposit is about the consistency of fresh plaster on a wall and about the same thickness.

We cleaned this pipe line once by dragging a set of scrapers through it, while pumping water through.

A Trial With Compressed Air

Then we decided to try cleaning this pipe with a mixture of water and air, and it worked so well that we have cleaned it by this method once each year ever since.

The scheme is very simple. We clean a mile at a time. We remove a 4 ft. section of pipe for an outlet. We pump the greatest volume of water our well pumps will handle, which is approximately 500 gpm., and at the same time force air into the pipe from compressor. The combined volume of air and water is thus forced through the pipe at a rather high velocity.

The air bubbles seem to join and accumulate to form air pockets of considerable size. Then, when the heavy slugs of water, following these light slugs of air, ram against the walls of the pipes a considerable force and scour results. Pieces of scale as much as 2 inches thick and of various widths are blown out of the pipe. For the most part, however, the material is broken up into very small pieces while traveling with such speed and turbulence.

Procedure

When we clean the two-mile main (one mile at a time) we first remove a four-ft. section of the pipe at a point where it crosses a ditch half way between the wells and the purification plant. We connect the air hose from the compressor to the pipe line near the wells. In fact, we use a piece of 1-in. copper tubing instead of a hose. We start the pumps of both wells pumping all the water through the pipe we can and start the compressor pumping all the air through the pipe we can. After cleaning the mile of main from the wells we move the compressor to the half way point, open the main at the purification plant and clean the last half just as before.

The compressor in the accompanying picture is rated at 210 cu. ft. per min. We have at different times used one rated at 80 cu. ft. per min., one rated at 110 cu. ft. per min., and also one rated at 160 cu. ft. Each one of them did the job, but the larger they are the better and faster they do it.

With the smaller compressors we have found it better to have a large receiver on the compressor and admit the air into the pipe at about one minute intervals on 30 and off 30 seconds. With the larger compressors this intermittent operation is unnecessary.

The Le Roi Compressor Connected to Main with 1-in. Copper Tubing
(Compressors from 80 to 210 cu. ft. min. capacity have been successfully used for the air-shooting operation.)

An Easy Four-Hour Job per Section

The time required with a 210 cu. ft. compressor is only about four hours on each mile. The water flows about fifteen minutes before the air starts to come through, then it starts a sort of coughing and sneezing. A lot of air will blow out, then a lot of water, rather brown and thick, carrying as much as 10 per cent of its volume of the loosened and pulverized scale of iron and silt. In about four hours

Main Cleaning by the Air-Shooting Method
(Intermittently a slug of air and little water followed by a water slug and little or no air.)

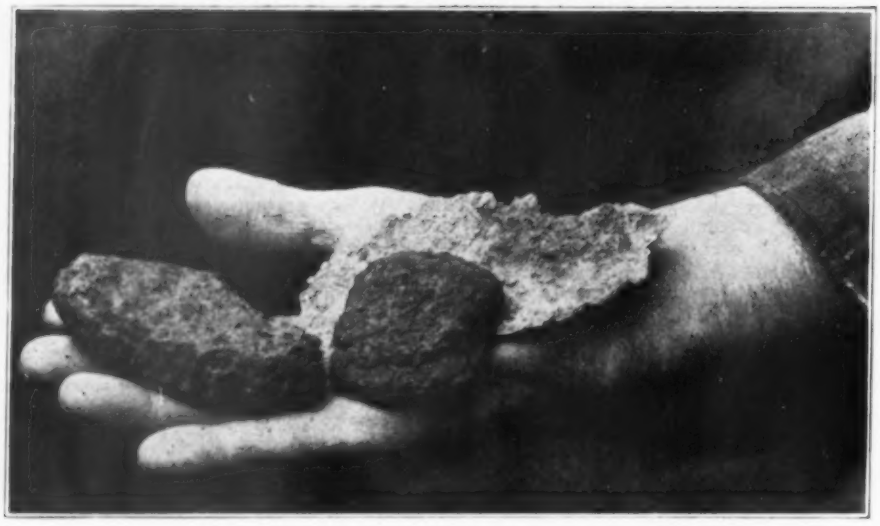


Exhibit "A"—Specimens of Encrustation Removed
(Some pieces measured 2 inches in thickness and 3 to 4 inches in width from the 8-in. main.)

the water flows clear again, and the job is finished.

As to the pictures of the scale chunks my guess is that it all started out when it broke loose as various sizes of chunks, little and big, but in its hurrried journey through the pipe the most of it was crushed and ground, so that the chunks we recover are only those that broke loose within a few hundred feet of the open end of the pipe.

As for the different pictures of water and air coming from the outlet, these are pictures of the same outlet taken within about a minute of each other. It naturally works intermittently that way—a blast of air for maybe a minute and then a lot of water with not so much air in it.

Perhaps the effect of the air-water method of loosening the pipe scale can best be explained as something similar to hydraulic-mining, wherein the side of a mountain composed of rather solid materials can be torn down and sluiced away by the high velocity streams of water used. In addition, there must be a multiple water hammer effect within the main, due to the inrush of slugs of water following or tumbling through the air pockets. This would account for the jarring loose of relatively large slabs of incrustation. In any event the higher the velocity of air-water flow through the main the more effective and speedy is the cleaning.

Since that time we have cleaned out the well once each year with an air-lift. The sand, etc., is all removed in less than an hour, with no noticeable wear on anything. It takes about an hour to install the air-lift and about the same length of time to dismantle it, so the whole job is done in three hours instead of three days. The way an air-lift works is very simple. There are no valves except those in the air compressor. You do not need any jet or foot-piece for the air-lift. A string of 2-in. pipe, open on bottom and top, is lowered into the well to the bottom, and then raised to just off the bottom. Inside the 2-in. pipe a ¾-in. string of pipe carries the air from the compressor and releases it on the inside of the 2-in. riser. The air-water mixture rises up the 2-in. riser and flows out with considerable agitation and velocity. It is the high velocity which brings up the sand and also any small gravel that may be there.

As was stated, this method is a great time and labor saving scheme for clearing deep wells of sand. For the job any compressor is sufficient as long as it is not smaller than about a 5 hp. size. The amount of air that brings up the most water is the proper rate of air feed for this job.

Removal of Sand From Wells

One of our gravel wall wells leaks a fine sand. When it accumulates in the well to a height which is still several feet below the suction pipe on the pump it is sucked up into the pump causing excessive wear on impellers and bowls.

We succeeded in removing the sand once with a duplex suction pump operated by two men with a hand lever, while a third man lowered a suction pipe slowly into the sand. That job took three men three days, and wore out six sets of pump leathers.

EQUATION OF PIPES

It is frequently desired to know what number of pipes of a given size are equal in carrying capacity to one pipe of a larger size. At the same velocity of flow the volume delivered by two pipes of different sizes is proportional to the squares of their diameters; thus one 4-inch pipe will deliver the same volume as four 2-inch pipes. With the same head, however, the velocity is less in the smaller pipe, and the volume delivered varies about as the square root of the fifth power. This table is calculated on this basis. The figures opposite the intersection of any two sizes is the number of the smaller-sized pipes required to equal one of the larger; thus one 4-inch equals 5.7 two-inch.

Dia. in.	1	2	3	4	5	6	7	8	10	12	14	16	18	20	24	30	36
2	5.7	1.															
3	15.6	2.8	1.														
4	32.	5.7	2.1	1.													
5	55.9	9.9	3.6	1.7	1.												
6	88.2	15.6	5.7	2.8	1.6	1.											
7	130.	22.9	8.3	4.1	2.3	1.5	1.										
8	181.	32.	11.7	5.7	3.2	2.1	1.4	1.									
10	316.	55.9	20.3	9.9	5.7	3.6	2.4	1.7	1.								
11	401.	70.9	25.	12.5	7.2	4.6	3.1	2.2	1.3								
12	499.	88.2	32.	15.6	8.9	5.7	3.8	2.8	1.6	1.							
13	609.	108.	39.1	19.	10.9	7.1	4.7	3.4	1.9	1.2							
14	733.	130.	47.	22.9	13.1	8.3	5.7	4.1	2.3	1.5	1.						
15	787.	154.	55.9	27.2	15.6	9.9	6.7	4.8	2.8	1.7	1.2						
16		181.	65.7	32.	18.3	11.7	7.9	5.7	3.2	2.1	1.4	1.					
17		211.	76.4	37.2	21.3	13.5	9.2	6.6	3.8	2.4	1.6	1.2					
18		243.	88.2	43.	24.6	15.6	10.6	7.6	4.3	2.8	1.9	1.3	1.				
19		278.	101.	49.1	28.1	17.8	12.1	8.7	4.8	3.2	2.1	1.5	1.1				
20		316.	115.	55.9	32.	20.3	13.8	9.9	5.7	3.6	2.4	1.7	1.3	1.			
22		401.	146.	70.9	40.6	25.7	17.5	12.5	7.2	4.6	3.1	2.2	1.7	1.3			
24		499.	181.	88.2	50.5	32.	21.8	15.6	8.9	5.7	3.8	2.8	2.1	1.6	1.		
30								27.2	15.6	10.0	6.7	4.8	3.6	2.8	1.75	1.0	
36									24.6	15.6	10.6	7.6	5.7	4.3	2.76	1.6	1.0

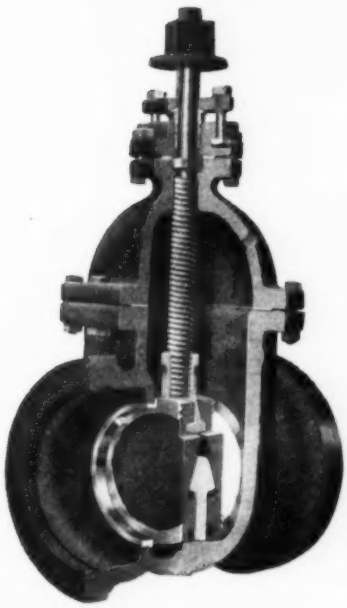
M & H VALVE AND FITTINGS COMPANY

ANNISTON, ALABAMA

VALVES, HYDRANTS AND WATER WORKS ACCESSORIES

Efficient domestic water systems, sanitary sewage systems, and fire protection for municipalities involve a great number of control valves and hydrants. M & H products with their record of high quality, rugged strength and dependability can safely be recommended.

The Mark of Quality



M & H FIRE HYDRANTS

Conform to latest A.W.W.A. specifications. Simple, rugged design minimizes maintenance costs. Features are:

1. **Dry Top—Operating threads protected from action of water. No rust, corrosion or freezing.**
2. **Easy Lubrication of operating nut, threads and packing through lubricating screw in top of operating nut.**
3. **Revolving Head, outlets faced in any direction.**
4. **Addition of Steamer Nozzle, without digging up hydrant or requiring complete new barrel.**
5. **Lengthening of Hydrant without digging up or requiring complete new barrel.**
6. **Double Lead Gaskets on Bronze valve seat.**
7. **Removal of Bronze Seat, or any working part, without digging up Hydrant.**
8. **Double Drain Valves, absolutely positive, insuring quick and complete draining of Hydrant.**
9. **Lugs on Bell of Hydrant Shoe for strapping to the water main, if desired.**
10. **Compression Type. Water pressure keeps valve tight.**

SPECIAL TRAFFIC MODEL FIRE HYDRANT

Equipped with cast iron bolts and breakable coupling on the stem. Breakage due to traffic collision is limited to these cast iron parts which are easily and quickly replaced without shutting off the pressure.

M & H A.W.W.A. GATE VALVES

Iron body, bronze mounted gate valves are furnished in the double disc parallel seat or solid wedge types with non-rising stem, outside screw and yoke, or with sliding stem and lever. Supplied to fit any standardized pipe connections. By-pass valves can be furnished, unless otherwise specified, in sizes according to A.W.W.A. specifications.

SPECIAL TYPES

Hydraulically Operated: **for remote control of operation and for quicker, easier opening or closing. Can be supplied in any of the standard sizes of M & H A.W.W.A. gate valves, either high or low pressure.**

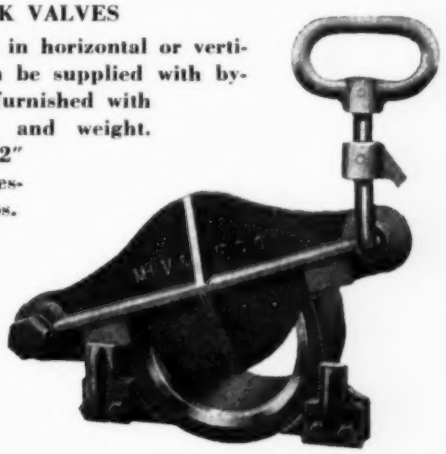
M & H Square Bottom Gate Valves: **specially designed for operation in any position. Particularly recommended for use in intake towers or at the foot of dams; for pressure regulation by throttling the flow of water in centrifugal pump discharge lines; for regulation of flow in feed line to a filter bed; and for flow regulation from a reservoir where there is unbalanced pressure against the gates.**

PRESSURE CLASSIFICATION—2″ TO 30″ SIZES

Class	Working Pressure	Hydrostatic Test
AA	0 - 25 lb.	50 lb.
A	26 - 50 lb.	100 lb.
B	51 - 100 lb.	200 lb.
C	101 - 200 lb.	350 lb.

CHECK VALVES

For installation in horizontal or vertical position. Can be supplied with by-passes. May be furnished with an outside lever and weight. Sizes from 2″ to 12″ for working pressure up to 200 lbs.



OTHER PRODUCTS

Tapping Valves
Mud Valves
Shear Gates
Flap Valves
Wall Castings
Floor Stands
Flanged Fittings
Flange and Flare Fittings
B & S Fittings
Cutting-In Tees
Valve Boxes
Special Castings

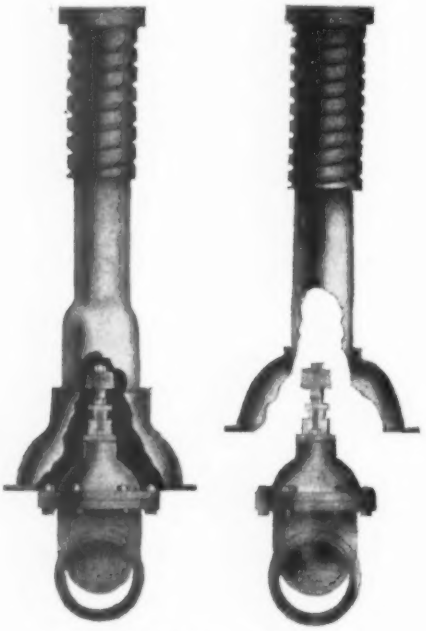
GATE VALVE CARE AND MAINTENANCE

By ROGER W. ESTY

Superintendent, Water and Sewer Board, Danvers, Mass.

TOO commonly, one of the most neglected of the routine operations in a water works system is the care and maintenance of gate valves. In some of the larger cities there are maintenance crews created particularly for this type of work. The crew is generally made up of some of the older men who are experienced in this work, due to their long service with the department or the water company.

They are furnished with a truck equipped with all the necessary tools, wrenches and spare parts, and they may also have built into the truck a mechanical operating device to open and close the gate valves. Smaller towns are more often than not unable to give proper attention to their gates, due primarily to lack of sufficient man-power to do this work and carry on the many other essential activities common to a water works plant.



Valve Box Settings

On the left is a setting as it is pictured in catalogs, and generally installed. To my way of thinking, the method of putting the valve nut-up in the contracted section is improper. On the right is a suggested better way for the several reasons cited in the text. Possibly this may suggest an advantage to be gained in an improved design of this type of box to give better overall service.

My water works experience goes back over a period of 27 years. During that time I have located, measured and plotted onto cards and maps every hydrant, gate valve, and all of the pipe in our system. I have opened and closed every gate valve many times. It was 20 years ago that we first had a water waste survey made of our system and, as many know, this necessitates the opening and closing of essentially every gate valve in the system This type of work we have continued every second year since, which affords added opportunities of locating and operating all of our gate valves.

Main Flushing Reveals Gate Valve Conditions

Occasionally our piping system is entirely flushed out, street by street, and this again means the operating of nearly every gate valve, and some have to be opened and closed several times during this flushing operation if properly conducted.

From this work experience is gained in the knowledge of what to expect of gate valves and the remedies that are used in perfecting their operation.

Stiff Operation a Main Trouble

One of the main difficulties, if not the main difficulty, we find with gate valves is that they turn hard. As years go on, if such valves are not operated occasionally they become more difficult to operate and in some cities and towns it takes two men, or even as many as four and six men, to close down a gate valve even during a testing period.

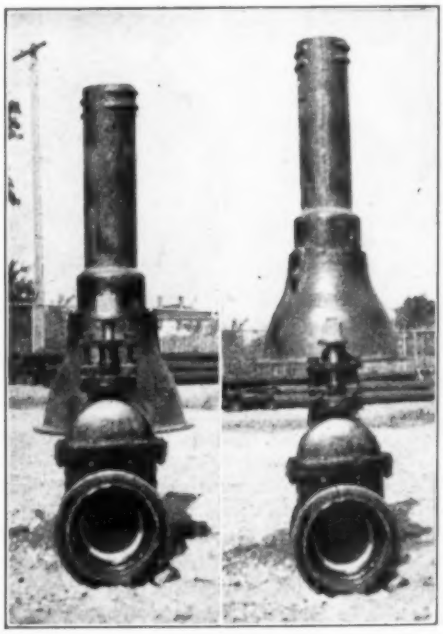
My experience does not go beyond a 20-inch gate valve, but it seems to me that the same principles and characteristics are applicable to all sizes.

A great deal of the indifference toward gate maintenance can be traced to the swivel chair operator. By that I mean the man in charge of the water works who has never experienced the opening and closing of all of the gate valves in his system. If he made tests of his system, such as a water waste survey, and had to work all night opening and closing these gate valves himself, he would soon issue an order to do something about making them operate easier. But generally, it is below his dignity to leave his swivel chair to do this type of work, to find out first hand the physical condition of his system. He doesn't care; he doesn't have to operate them; let the men do it, even if it does take two, four or six to do the job.

The Remedy

What are the difficulties we encounter; what causes them, and how can they be remedied? Why should it take four men to close a gate valve when one man should do it?

Why do stems get bent and broken? What is the cause of all this? Is it because the mechanism is not correct in design, or that the mechanism is not made heavy enough? I feel that the manufacturers as a general rule put on the market a gate valve that will meet all reasonable conditions according to our water works standard specifications. However, I do think the manufacturers do lose sight of one very important factor, and that factor is the packing, and in my opinion, if improper or



A photographic attempt to indicate the advantage of setting the box bonnet higher, giving more clearance between box walls and nut and stem of the valve. The usual setting (left) is in truth a "rock trap," while the other permits rocks to pass by; also makes for easier key connection with the nut should the box become off-center.

neglected packing is not the direct cause, it is at least the seat of 90 per cent of all gate valve troubles.

Many ask, why does the packing have such an important bearing on the ease of operation of the gate valve? Well, the packing gets dry and hard as the years go on. This dry packing acts as a brake on the valve stem.

Take, for instance, your automobile—the brake linings are dry and the brake drum of the wheel is smooth and dry. When the pressure is exerted against one another it creates friction, and

Danvers' Alemite Lubricating Outfit Servicing a Geared Valve.

this friction creates your braking or stopping power. Sometimes at high speeds this friction actually locks the wheels and causes fatal accidents.

On the other hand, pack the brake drums with grease and then attempt to stop your car. The grease eliminates the friction, therefore there is no friction created to stop your car.

Take a rope and wind it around an inch pipe three or four times and draw it tight and then attempt to turn the pipe. You will find you can't do it. Then grease the rope thoroughly and you will find that you can turn the pipe very easily. Try it for your own satisfaction.

Did you ever try holding an eel in your hand? If you have, you probably found that it was nearly impossible to hold it because it was so slippery. If you can get your gate valve stem and packing in the slippery condition you find the eel, you'll have no more hard turning gate valves.

However, there is a difference in the mechanism in some of the gate valves and one make may operate a little different than another make when new. But on the whole, modern gate valves should operate more or less in the same easy manner.

A Case of Proof

Several years ago, while making a water waste survey during nights, we came across a 12-inch gate most difficult to operate. It took the combined efforts of two of us to open and close the gate. The next day I had the gate dug up and repacked. It seems hardly believable, but it could then be turned with just one finger against the cross-bar of the gate key.

Such ease of operation surely saves breaking or bending the valve stems and makes the operation of the gate a pleasure instead of a dreaded job.

Some Packing Pointers

On many of our gate valves and nearly all of our hydrants we have removed the original braided packing and inserted a metallic plastic packing, with two or three strands of flax string type packing on top to keep it from squeezing out when the packing gland is tightened down.

After taking out all of the braided packing, we squirt down around the stem near the packing plate some kerosene or light lubricating oil. We then fill up the stuffing box with a metallic packing that comes in a loose plastic form or in string form. We then put on the stuffing box follower and tighten it down. We then open and close the valve a few turns and then tighten it some more. If it needs a little more packing we insert some and go through the operation again. This method has solved our packing problems and made hard turning gate valves easy turning, and makes fun out of a disagreeable job.

The Larger Valves

In the large gates we drill a hole through the packing plate and insert an alemite fitting. These gate valves still have the braided packing in the packing box. By connecting a grease gun to this fitting we can apply by means of our air compressor about 3,500 pounds pressure and this forces the grease in and around the stem and packing and does a very satisfactory job of lubricating.

It does such a good job on these gate valves that it is a monotonous one man job of opening and closing the valve when testing; in fact, a boy 10 years old can operate the valve.

Large gate valves should have an ample size manhole constructed around them so that a man can get down to the gate and repack it. Smaller gates can be handled more economically by using a 5¼ or 7-inch valve box over the gate with the cover flush with the road.

The gears of a geared gate should be enclosed in a housing with the gears running in oil. If the gears are not housed then they will collect rust and dirt in between the gears or teeth,

Danvers' Method of Marking Street Gate Locations.
Yellow figures stenciled on black field on nearest pole.

making them fit tight and bind, causing the gate to operate hard. Dirt falling down into the hole when the cover is picked up causes some of this trouble.

We have eleven 20-inch open geared gates and we wish we had purchased the oil enclosed style. That surely was an error on our part, but our experience with them has taught us to advise others to buy the oil enclosed style.

We have constructed a shield that fits over the gears and the operating nut and fastens to the bolts holding the stuffing box to the bonnet of the gate. This has proved very satisfactory and the dirt does not get into the gears. This gives us the opportunity to keep them well greased.

Improper Valve Box Setting

Many gate valve catalogues show what, in my opinion and experience, is an improper method of setting the box over the gate. Pick up any catalogue and turn to the gate box section

showing the 5¼ or 7-inch box. You will notice that the base or pot sets down over the top of the gate so that the base of the box is even with the flange in the center of the gate. Then the upper section, or middle section, is set onto the base, leaving the operating nut up in this section.

My contention of it being an improper setting and causing maintenance troubles is that if rocks do get into the boxes (and the kids sure do put them in sometimes), that the rock cannot go down past the operating nut. It gets wedged in so hard sometimes that it is impossible to get the key onto the operating nut, and if you do, you cannot turn it. If the box is pushed to one side slightly, the box then comes up against the operating nut and prevents putting the gate key onto the operating nut.

If, on the other hand, the base or pot is set so that the base is up at the level of the stuffing box plate, rocks then can roll to one side into the base, and if the box is tipped there is a greater possibility of getting the gate key onto the operating nut.

In my opinion, box setting is a very important part of your gate maintenance work.

Location Records

Location plans of gate valves should be carefully prepared and measurements should be taken from permanent benches, such as to other gate valves, hydrants, catch basin grates, manhole covers, curbs, etc., and not from telephone poles, trees, walls, fences, etc.

These measurements should be on cards and on sheets in bound books for quick reference. Each should have a number and these can be painted on the underneath side of the valve box cover if desired.

Stencilling of measurements onto buildings, poles, etc., are helpful for quick locating. Numbers can be nailed onto poles or buildings that will stay on as long as the pole or building remains in place. We paint a black square on the reference object and nail on the metal numbers that have been sprayed with an orange colored paint. The contrast makes it conspicuous from any other type of marking.

Removing Recalcitrant Box Covers

Sometimes the gate box cover gets sealed in with tar, or in the winter is frozen in. This can be very easily overcome by pouring a little gasoline on it and setting it on fire. In a few moments the cover can be easily removed.

Quite often it is found difficult to close the gate tightly. This is generally caused by tuberculation in the valve guides and seat. By opening and closing several times this incrustation breaks off and the velocity of the water between the gate and the seat of the valve will most always flush out, allowing the gates to eventually properly seat and closing off entirely the flow of water.

Gate valve work is not expensive. It is a tedious job but can be made very interesting by the various things that have to be done, such as checking measurements, marking poles or buildings, opening and closing, repacking, and the resetting of the gate box at higher elevation.

If a few of these suggestions are followed, most of your gate valve worries will be a thing of the past:

Good plans and measurements.

Stencilled or metallic reference numbers on poles, buildings, etc.

Gate box covers flush with the surface of the ground.

The base of the box well above the center flange of the valve.

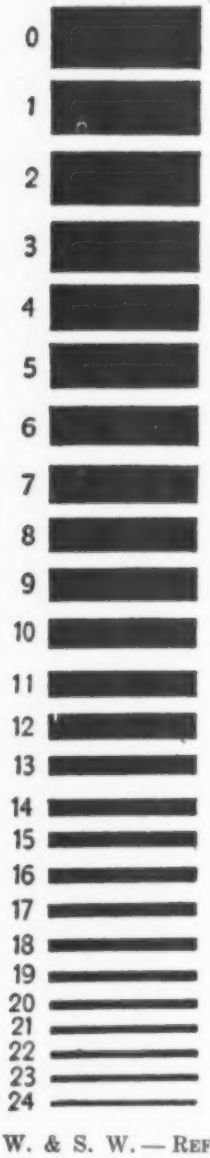
Opening and closing each valve on a yearly schedule.

Last, and the most important, proper packing and lubrication.

And a good motto is:

"More turning of gate stems and less of swivel chair stems."

"Know your gate valves!"



Thickness and Weight of Sheets and Plates

Number of Gauge	U.S. Standard Gauge Adopted by U. S. Government July 1, 1893			Birmingham or Stubs' Gauge		American or Brown & Sharpe's Gauge		Thickness of Wire: Washburn & Moen Gauge
	Thickness, Inches		Weight, Pounds, per Sq. Ft.	Thickness, Inches	Weight, Pounds, per Sq. Ft.	Thickness, Inches	Weight, Pounds, per Sq. Ft.	Thickness, Inches
0000000	1/2	.5000	20.4	.....	.....	.....	.....	.....
000000	15/32	.46875	19.125	.....	.....	.580	23.6	.....
00000	7/16	.4375	17.85	.....	.....	.5165	21.0	.....
0000	13/32	.40625	16.575	.454	18.5	.46	18.71	.3938
000	3/8	.375	15.30	.425	17.28	.409	16.71	.....
00	11/32	.343	14.025	.38	15.45	.364	14.88	.331
0	5/16	.312	12.75	.34	13.82	.324	13.26	.307
1	9/32	.281	11.475	.30	12.20	.289	11.80	.283
2	17/64	.265	10.837	.284	11.55	.257	10.51	.263
3	1/4	.25	10.2	.259	10.53	.229	9.36	.244
4	15/64	.234	9.562	.238	9.68	.204	8.34	.225
5	7/32	.218	8.925	.22	8.95	.181	7.42	.207
6	13/64	.203	8.287	.203	8.25	.162	6.61	.192
7	3/16	.187	7.65	.18	7.32	.144	5.89	.177
8	11/64	.171	7.012	.165	6.71	.128	5.24	.162
9	5/32	.156	6.375	.148	6.02	.114	4.67	.148
10	9/64	.140	5.737	.134	5.45	.101	4.16	.135
11	1/8	.125	5.1	.12	4.88	.09	3.70	.120
12	7/64	.109	4.462	.109	4.43	.08	3.30	.105
13	3/32	.093	3.825	.095	3.86	.072	2.94	.092
14	5/64	.078	3.187	.083	3.37	.064	2.62	.080
15	9/128	.070	2.868	.072	2.93	.057	2.33	.072
16	1/16	.062	2.55	.065	2.64	.05	2.07	.063
17	9/160	.056	2.295	.058	2.36	.045	1.85	.054
18	1/20	.05	2.04	.049	1.99	.04	1.64	.047
19	7/160	.043	1.785	.042	1.71	.035	1.46	.041
20	5/80	.037	1.53	.035	1.42	.032	1.31	.035
21	11/320	.034	1.402	.032	1.30	.028	1.16	.032
22	1/32	.031	1.275	.028	1.14	.025	1.03	.....
23	9/320	.028	1.147	.025	1.02	.022	.922	.....
24	1/40	.025	1.02	.022	.895	.020	.82	.....
25	7/320	.021	.892	.02	.813	.017	.73	.....
26	1/50	.018	.765	.018	.732	.015	.649	.....
27	11/640	.017	.701	.016	.651	.014	.579	.....
28	1/64	.015	.637	.014	.569	.012	.514	.....
29	9/640	.014	.573	.013	.....	.011	.461	.....
30	1/80	.012	.51	.012	.....	.01	.408	.....

STANDARD GAUGES*

Sheets, Plates and Wire

Sheet mills roll steel sheets to U. S. gauge unless otherwise ordered. Plate mills usually roll heavy plates, 3/16 and heavier, and light plate No. 8 to No. 12, to Birmingham gauge. In figuring weights of steel plates add to above the allowance for overweight, adopted by Association American Steel Manufacturers. All steel shee's in our *stock are rolled to the U. S. Standard Gauge. Brass is rolled to thickness by Brown & Sharpe's American Gauge. Copper is rolled to thickness by Stubs' or Birmingham Gauge.

* From Link-Belt Catalog.

HYDRANT MAINTENANCE

By E. T. CRANCH

Former President and Manager, New Rochelle Water Co., New Rochelle, N. Y.
Now Director Public Works, New Rochelle, N. Y.

GOOD housekeeping is always essential. Women are judged by the manner in which they keep their homes—neatness, if you please. Neatness in water works operation should also be considered essential, and perhaps we should ask for the ladies' advice on our water works "housekeeping" more often than we do.

The Hydrant as a Symbol

Fire hydrants are, without doubt, the most conspicuous and most frequently commented on part of any water works plant. Yet too often these symbols of the water utility suffer from neglect. In the good old days when one could tour the country without worrying about gasoline and tires it was always refreshing to come to a town with bright, freshly painted hydrants, and these always stood out in sharp contrast to the many communities where the hydrants were drab and neglected. We in the water works fraternity should practice "good housekeeping" for our satisfaction as well as for the impression it makes on others.

Paying Procedure

Twice each year every fire hydrant should be given a routine inspection—once in the spring and once in the fall. This inspection should include a pressure test. This test is important for three reasons: it checks on the closing of the drip valve, it reveals any cracks which may have developed from either freezing or external damage, and it proves whether the nozzles are tight. When you first apply the pressure test, always stand back of the hydrant. We have seen serious injury caused by a nozzle flying off and striking a man in the stomach.

Outside of the condition of the hydrant, the pressure test also at times gives valuable information as to underground leaks. The pressure observed should always be compared with that recorded on previous tests. If there is any material reduction, the matter should be at once investigated. This method has sometimes given the first clue to locating serious underground leakage.

A dependable worker given a thoroughly equipped truck for hydrant and valve maintenance work represents money well spent

Importance of Lateral Valves And Their Maintenance

Every hydrant should be equipped with a gate valve on the lateral. This is essential to the efficient operation of any water works system. Otherwise a damaged hydrant may necessitate the shutting down of a considerable length of street main and the putting out of service of several other hydrants while repairs are being made to one. This might easily prove very embarrassing to a water department as well as a water company, especially if a hydrant is damaged during a large fire. If any municipality still has hydrants without a gate valve on the lateral we strongly recommend that such gate valves be installed at the first opportunity they can be obtained.

THE NEW ROCHELLE WATER CO.,
NEW ROCHELLE DIVISION
New Rochelle, N. Y. .....19.....

DAILY HYDRANT REPORT

No. of Hyd.	STREET	Press.	Time Taken	Greased	Packed	New Bolts	Painted	Numbered	Unusual Repairs

FORM 6 (10-4-39)

Fig. 1.—Daily Hydrant Report Form Used for Recording Routine Maintenance Inspection and Repairs.

Report Records

Figure 1 is a form of daily report for work on hydrants which we have found very satisfactory. It will be noted that this form calls for "No. of Hyd." We have found it convenient to number all of our hydrants serially. This number is stenciled at the base of the hydrant on the side facing the street. Figures about 2 inches high are used. It will be noted that following the pressure column ("Press.") there is a column "Time Taken." In comparing pressures it has been found helpful to know the time of day at which each pressure was taken. The next five columns are simply checked off as the operations are performed. In the last column any unusual repairs required are noted.

Painting Policy and Practice

We have found it good policy to paint all hydrants once a year. In this way the hydrants always have a well groomed look and are a credit to the company. If a high grade enamel paint is used, the hydrant may look quite passable for a period of two years, but at the end of two years it is difficult to apply a new coat of enamel satisfactorily without a lot of wire brushing on the old coat. We have found a semigloss paint to be most satisfactory. It holds up very well for a year and is easy to

R-88

S.P. 13640

NO.

LENGTH OF LATERAL ft. HIGHWAY ☐ PRIVATE ☐

DIAM. OF LATERAL in. CUTLETS

SMITH TAP ☐ REG. VALVE ☐

DISTANCE HYD. TO VALVE

DIAM. OF STREET MAIN in. HYD. BBL. SIZE in.

ELEVATION ft. DATE

REMARKS

DATE	HYDRANT		PIPE		VALVE SIZE	G.B. OR M.H.	WORK ORDER
	MAKE	VALVE SIZE	SIZE	LENGTH			

DATE	PRESSURE AT INSPECTION	DATE	PRESSURE AT INSPECTION

NO.

TYPIST PLEASE NOTE—THIS SCALE CORRESPONDS TO TYPEWRITER (PICA) SCALE—SET PAPER GUIDES SO THAT CARD SCALE WILL REGISTER WITH MACHINE SCALE WHEN CARD IS TURNED INTO WRITING POSITION. START INDEX THREE (3) POINTS FROM LEFT EDGE OF CARD. USE OTHER POINTS OF SCALE FOR OTHER DIVISIONS OF VISIBLE TITLE. SET TABULATORS TO INSURE PERFECT ALIGNMENT OF EACH DIVISION OF INFORMATION. FOLD BACK OR REMOVE STUB AFTER TYPING. USE NEW TYPEWRITER RIBBON.

KARDEX VISIBLE DIVISION 886-200-85814-'38 REMINGTON RAND INC.—13 Printed in U.S.A.

Fig. 2.—Permanent Maintenance Record Form of the Kardex System.
(Gives all essential operating information at a glance. Also provides the important continuing property record now increasingly demanded by State Public Service Commission.)

repaint. We have painted as many as 140 hydrants with one gallon of paint.

Immediately after a hydrant is painted, be sure a "wet paint" sign is securely fastened to the hydrant. It is surprising how much clothing can be damaged by brushing up against a freshly painted hydrant, and unless the wet paint sign is there, the water utility (company or department) will be faced with paying damages.

We have tried using a portable spray pump but have found it wasteful of paint and that we could paint just as many hydrants per day by hand.

Packing and Lubrication

For packing we use jute impregnated with tallow. This has proven very satisfactory. For lubrication we use a grease with a graphite base. We have tried various types of grease and the graphite base grease is the only one we have found which will not cause the caps to stick, especially in cold weather.

Cap Chains Useless Impedimenta

The common practice is to have the caps fastened by chains to the hydrant barrels. We found the fire departments in trying to get connected to a hydrant in a hurry were often greatly annoyed by the chain. We therefore tried the experiment some ten years ago of removing all the chains. We feared that caps might get lost or misplaced during a fire so we equipped each fire truck with an extra cap, but to date none of these extra caps have been used and the fire departments are greatly pleased with the elimination of the chains.

It is essential at all times to have the full cooperation of the fire department and arrangements should be made to have the fire department report to the water department after it has used any hydrant. The water department should then make a special inspection of this hydrant to see that everything about it is all right. The fire department should also be instructed never to force a hydrant in trying to close it. If it does not close readily, have the water department or company notified.

Continuing Records

Figure 2 illustrates a form of permanent hydrant record which is used in a Kardex file. This card gives all the essential operating information as well as that necessary for the maintenance of a continuing property record such as is required now by several Public Service Commissions.

TABLE OF EFFECTIVE FIRE STREAMS

Using 100 feet of 2½-in. ordinary best quality rubber-lined hose between nozzle and hydrant or pump.

Smooth Nozzle, Size	¾ Inch						⅞ inch				
Pressure at Hydrants, lbs.	32	43	54	65	75	86	34	46	57	69	80
Pressure at Nozzle, lbs.	30	40	50	60	70	80	30	40	50	60	70
Press. lost 100' 2½" hose	2	3	4	5	5	6	4	6	7	9	10
Vertical Height, feet	48	60	67	72	76	79	49	62	71	77	81
Horizontal Distance, feet	37	44	50	54	58	62	42	49	55	61	66
Gallons Discharged per min.	90	100	116	127	137	147	123	142	159	174	188

Smooth Nozzle, Size	1 Inch						1⅛ Inch				
Pressure at Hydrant, lbs.	37	50	62	73	85	97	41	54	67	80	93
Pressure at Nozzle, lbs.	30	40	50	60	70	80	30	40	50	60	70
Press. lost 100' 2½" hose	7	10	12	13	15	17	11	14	17	20	23
Vertical Height, feet	51	64	73	79	85	89	52	65	75	83	88
Horizontal Distance, feet	47	55	61	67	72	76	50	59	66	72	77
Gallons Discharged per min.	161	186	208	228	246	263	206	238	266	291	314

Smooth Nozzle, Size	1¼ Inch						1⅜ Inch				
Pressure at Hydrant, lbs.	46	60	75	90	104	119	52	69	86	102	119
Pressure at Nozzle, lbs.	30	40	50	60	70	80	30	40	50	60	70
Press. lost per 100' 2½" hose	16	20	25	30	34	39	22	29	36	42	49
Vertical Height, feet	53	67	77	85	91	95	55	69	79	87	92
Horizontal Distance, feet	54	63	70	76	81	85	56	66	73	79	84
Gallons Discharged per min.	253	292	326	357	386	413	307	354	396	434	469

PNEUMATIC CAULKING OF PIPE JOINTS

And Other Water Main Construction Practices

By H. WALTER HORN
Construction Engineer
Bureau of Water, Allentown, Pa.

ALLENTOWN, Pa., a city of 100,000 persons, has a municipal water supply acquired in 1869 at a cost of $98,958 when it had only 10 miles of water mains. Today, the system is valued at $6,800,000 and has 170 miles of mains.

The size of these mains is set by city ordinance and they must be laid according to specifications. In excavating, the contractor is required to hold to the line and grade established by the city engineering department. Where rock is encountered, it must be removed to a depth of 8 inches below subgrade and replaced with padding, compacted in 4-inch layers. When the subgrade is ready, bell holes are dug in advance so the pipe-layers will not be hindered. The pipe, which has been placed alongside the excavation, is rolled into position, swabbed out, and lowered into the ditch either by tripod or ropes. Particular attention is paid to the unloading of the pipe. All pipe is hauled by contract on flat bottom trucks, and removed from the trucks by skids and ropes. No pipe is allowed to be dropped or rolled from the truck.

Joint Packing

After the pipe is placed in the ditch, a single strand of square braided jute is put around the spigot end of the pipe, and the pipe is then "pushed home." If the jute is properly placed and held, it has a tendency to roll into the bell, thus reducing the amount of packing needed. Another advantage of this type of jute is that it centers the spigot in the bell, thereby reducing wedging, which would place a strain on the bell and spigot.

After the pipe is brought to grade by placing a specified 2-in. x 6-in. x 16-in. block behind the bell, the joint is ready to be packed. The jute is driven into the bell to a depth of two and seven-eighths inches, the depth of lead specified for all joints. A round runner or snake is placed in position and the joint is poured in one operation. After the runner is removed the joint is ready for caulking.

Pneumatic Caulking Adopted

A search of the literature, in 1935, for information on the subject of air-hammer caulking of lead joints between two and twelve inches failed to reveal anything, but the procedure was nevertheless adopted as standard for Allentown. It was decided that an Ingersoll-Rand No. 100 air hammer would be used as it is small and light enough to permit a man to handle it easily, while running the joint in a smooth and continuous manner. A set of caulking tools, consisting of a cutting-in chisel and six other tools of standard sizes, completed the outfit.

The first problem was to determine the amount of air pressure that could be used in the hammer without damaging the pipes. By experiment and observation the following table of pressures was chosen for the work:

Pipe Size	Max. Pressure
12-in.	65 p.s.i.
8-in.	60 p.s.i.
6-in.	55 p.s.i.
4-in. (and less)	50 p.s.i.

These pressure readings are taken at the compressor and not more than 150 ft. of air hose is used.

Any person with a little mechanical ability can acquire the knack of air-hammer caulking. In practice, every tool that fits the joint is used, beginning with the cutting-in chisel and following with each tool in successive size, from small to large, with one pass around for each. When a joint is properly caulked the lead gate will practically fall off. Figs. 1 and 2 show the caulking tools in use.

After all pipes are laid and caulked, the line is filled very slowly with water in order that the chlorine sterilizing agent (placed in every other section) will be completely dissolved. Air is expelled from the pipe at the high point during the filling process. When filled, the line is isolated and tested at 150 pounds hydrostatic head. While under this pressure the joints are carefully inspected, as a perfectly dry joint is required. If the test is satisfactory the line is flushed thoroughly and put into service.

Bedding and Backfilling

In backfilling the ditch, particular attention is paid to the bedding of the pipe. A layer of earth is placed in the ditch until even with the top of the pipe, and enough water is run in to make a good puddle. A man in boots then straddles the pipe and, moving along slowly, stamps and spades the earth until the pipe is well bedded. Following this operation several methods are used to backfill the rest of the ditch. If done by hand, enough water is used in backfilling to pack the ground well until it is within 18 inches of the top of the ditch. Dry earth is used to complete the filling after which the whole is rolled by truck.

In some instances, especially W.P.A., hand tamping was used from the top of the pipe to the top of the ditch. If the backfilling is done mechanically, a foot of earth on top of the pipe is mandatory before a bulldozer or shovel can go to work. Rock larger than a man's head may not be used in the backfill. Where there is rock formation, mechanical backfilling is not permitted. After the ditch is filled and rolled, the Water Department's work is completed. The City Highway Department makes the permanent repairs to the streets, but the cost is assumed by the Water Department.

Fig. 1—Caulking a 12-In. Line on Bridge

Fig. 2—Caulking an 8-In. Line in Trench

Results From Pneumatic Caulking

Since 1935, when air-caulking was introduced into the specifications, twenty-eight miles of water mains have been laid. The success of air-hammer caulking is indicated by the fact that out of approximately fourteen thousand joints, only six 12-in. and three 8-in. had to be dug up and recaulked. Of these fourteen, three of the 12-in. joint leaks were directly attributed to an inexperienced caulker working in adverse conditions. In no instance has a fractured spigot or bell been discovered due to overcaulking. On several jobs air-caulking was permitted on two, three, and four-inch pipe. Needless to say, an experienced caulker was needed for this work.

In a recent city-wide leak survey no leaks or cracked pipes were discovered on any of the mains laid since 1935.

UNITED STATES PIPE AND FOUNDRY CO.

General Offices: **Burlington, New Jersey**

SALES OFFICES

Philadelphia Birmingham San Francisco Pittsburgh Cleveland Minneapolis Seattle
New York Chicago Boston Kansas City Dallas Houston Los Angeles

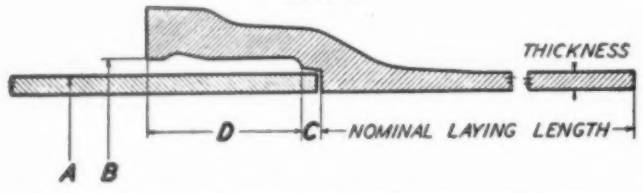
Makers of

SUPER-DE LAVAUD CENTRIFUGALLY CAST IRON PIPE
PIT CAST IRON PIPE AND FITTINGS
U. S. STANDARDIZED MECHANICAL JOINT PIPE
THREADED PIPE IN IRON PIPE SIZES
WEBRE INDUSTRIAL AND SUGAR APPARATUS
FLANGED PIPE AND FITTINGS
FLEXIBLE JOINT PIPE
LARGE CASTINGS TO ORDER
USICAST CAST IRON ROOF
USICAST CHEMICAL CASTINGS

Super-deLavaud Pipe with B&S Joints

Super-deLavaud Pipe with bell and spigot joints is available in all sizes from 3" to 24" and in 12-foot and 18-foot lengths. The joint is particularly adaptable for lead, cement, joint compound or rubber ring assembly. The centering ring insures easy alignment and uniform distribution of the jointing material. The process by which this pipe is produced assures concentricity, evenness of metal and freedom from sand or slag inclusions. The bell and spigot joint, made with lead or other jointing materials, shows ample strength to resist pulling apart. If required to meet service conditions, pipe will be furnished with special linings. All Super-deLavaud Pipe with bell and spigot joints are made to meet Federal Specification WW-P-421. Write for descriptive booklet.

TABLE I



Nominal Diameter Inches	Class or Maximum Working Pressure	Average Thickness	Nominal Laying Length			
			12-Foot Length		18-Foot Length	
			Weight of Pipe Pounds	Weight Per Foot Including Bell	Weight of Pipe Pounds	Weight Per Foot Including Bell
3	250	36	165	13 7	240	13 4
4	[illegible]	34	195	16 4	285	15.9
4	250	38	220	18 4	325	17.9
6	150	37	315	26 3	460	25.5
6	250	42	350	29 3	515	28.5
8	150	42	475	39 4	690	38.3
8	250	46	510	42 4	745	41 3
8	250	50	545	45.5	800	44 3
10	150	47	640	53 3	935	51 8
10	200	52	700	58 3	1025	56.8
10	250	57	760	63 3	1115	61 9
12	150	50	810	67 4	1180	65.6
12	200	57	905	75 4	1325	73 7
12	250	62	990	82 5	1450	80 7

Nominal Diameter Inches	Class or Maximum Working Pressure	Average Thickness	Nominal Laying Length			
			12-Foot Length		18-Foot Length	
			Weight of Pipe Pounds	Weight Per Foot Including Bell	Weight of Pipe Pounds	Weight Per Foot Including Bell
14	100	48	920	76 5	1340	74 3
14	150	55	1060	88 5	1555	86 3
14	200	62	1190	99 0	1735	96 3
14	250	69	1320	110 0	1930	107 3
16	100	52	1130	94 2	1645	91 4
16	150	60	1320	110 2	1935	107 4
16	200	68	1490	124 1	2175	120 7
16	250	75	1635	136 1	2390	132 7
18	100	56	1365	113 8	1990	110 6
18	150	65	1595	132 8	2330	129 6
18	200	74	1810	150 9	2645	146 9
18	250	83	2015	168 0	2950	163 9
20	100	58	1585	132 0	2305	128.0
20	150	68	1860	155 0	2720	151 0
20	200	78	2125	177 1	3105	172 4
20	250	88	2365	197 1	3465	192.4
24	100	64	2085	173 8	3035	168.6
24	150	76	2480	206 8	3630	201.6
24	200	88	2855	237.8	4170	231.6
24	250	1.00	3200	266 8	4690	260.6

Threaded Cast Iron Pipe Centrifugally Cast

Super-deLavaud Cast Iron Pipe is now being manufactured in "iron pipe sizes" with threaded joints to meet the demand for a better and more durable pipe. There are two distinct types of service for which Super-deLavaud Cast Iron Pipe may be used: pressure service for water, gas, steam or similar liquids and gases; and drainage service. Pressure pipe is made to meet the requirements of Federal Specifications WW-P-421 and is supplied in three classes: standard, extra-strong and double-extra-strong. Drainage pipe, used for waste, vent and drain work, is a lighter pipe for use in buildings and elsewhere where a tight screw-coupled joint is needed. Drainage pipe is made to meet the requirements of Federal Specifications WW-P-356.

THREADED CAST IRON PRESSURE PIPE

(Made to meet the requirements of Federal Specifications WW-P-421)

Size Inches	Class	Nominal Length, Feet	Outside Diameter, Inches	Nominal Thickness, Inches	Threads per Inch	Weight per foot Pounds
3	Standard	12	3.50	.36	8	11.08
	X-strong	12	3.50	.45	8	13.45
	XX-strong	12	3.50	.48	8	14.21
4	Standard	18	4.50	.38	8	15.34
	X-strong	18	4.50	.48	8	18.91
	XX-strong	18	4.50	.52	8	20.29
5	Standard	18	5.56	.40	8	20.22
	X-strong	18	5.56	.49	8	24.40
	XX-strong	18	5.56	.53	8	26.15
6	Standard	18	6.63	.43	8	26.13
	X-strong	18	6.63	.51	8	30.59
	XX-strong	18	6.63	.55	8	32.78
8	Standard	18	8.63	.50	8	39.85
	X-strong	18	8.63	.56	8	44.29
	XX-strong	18	8.63	.60	8	47.22

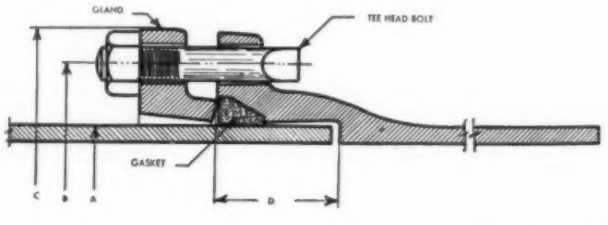
THREADED CAST IRON DRAIN PIPE

For Waste, Vent and Drainage Service

(Made to meet the requirements of Federal Specifications WW-P-356)

Size Inches	Nominal Length Feet	Outside Diameter Inches	Minimum Thickness Inches	Threads per Inch	Weight per Foot Pounds
3	12	3.50	.26	8	9.41
4	18	4.50	.29	8	13.75
5	18	5.56	.33	8	19.05
6	18	6.62	.38	8	26.22
8	18	8.62	.44	8	39.82

U. S. STANDARDIZED MECHANICAL JOINT



We are now prepared to furnish U. S. Standardized Mechanical Joint Pipe and Fittings in sizes from 3" to 24" with parts that are interchangeable with those furnished by other manufacturers of cast iron mechanical joint pipe.

NEW METHOD FOR CUTTING CAST-IRON PIPE*

By WENDELL R. LA DUE

Supt. and Chief Engr., Bureau of Water and Sewerage, Akron, Ohio

FOR some time leakage had been observed adjacent to the gatehouse of the equalizing reservoir at Akron, Ohio. This reservoir is of the covered type and has a capacity of 20 mil.gal., about one-half day's supply during peak consumption.

The leakage was believed to be through expansion joints in the reservoir wall, since the leakage appeared to be greater in the winter when the joints were wider, and also because more leakage was observed with a full reservoir than when the water was at a lower elevation.

From time to time the water in the reservoir was lowered, and the expansion joints were calked with lead wool. The leakage continued, however, and during the summer of 1944 it was decided to expose the outside of the joint opposite the point of observed maximum leakage. The joint was exposed for its entire depth and no leak was found.

Continued observation in the vicinity disclosed that the grass over an adjacent connecting main remained green throughout the hot summer drought. The connecting main was isolated by closing the valves to the reservoir and to the force mains. The flow of water which had been observed stopped almost immediately and began again as soon as water was supplied to the connection. After this it was certain that the leak was in the connection.

The connection of 36-in. cast-iron pipe, 52 ft. in length, is the only connection between the equalizing reservoir and the force mains and distribution system. The average cover over the connection is approximately 14 ft. With a full reservoir the head on the pipe is 32 ft. (14 psi.).

Construction information was meager. It was known that the pipe was 36-in. Class A pipe furnished under contract dated Sept. 12, 1912. The average weight of the pipe was 4,804 lb. per 12-ft. lgth., or slightly over the standard weight of 4,700 lb. per length. A piece of pipe removed calipered 0.99 in. thick, which is standard for Class A cast pipe. The connection was laid under contract of 2/6/13.

It was necessary to excavate a trench 19 ft. in depth by approximately 9½ ft. wide for a distance of approximately 25 ft. to expose the pipe. The excavation was complicated by the necessity of furnishing adequate support for the footing of a 15-ft. retaining wall abutting the excavation and for a concrete wall which crossed the trench at right angles.

The trench was excavated and sheeted as shown in the accompanying sketch. Excavation was facilitated by crane with a clamshell bucket and the excavated material hauled away. The sheeting was hand-driven, and 24-hour pumping was carried on to insure dry working conditions. The head on the pipe was reduced by carrying lower reservoir elevations, but the reservoir remained in service.

Upon exposing the pipe, it was found that the lead in a joint had "blown" and most of the leakage was coming from the top of the pipe. The lead was driven home sufficiently to hold the water; the trench dried up and pumping discontinued.

While engaged in calking the joint a 3-ft. longitudinal crack was discovered in the bottom of the pipe extending through the bell. Due to the low head on the pipe, together with the relief offered by the "blown" joint, no leakage had appeared through the crack. This condition changed a relatively easy repair job into a major one. The broken bell was almost directly under the cross wall, preventing easy removal and replacement of the pipe. The pipe was in rock, which also added to the difficulty of excavation.

Thought was given to two methods of making a repair as follows:

1. Welding in place. This was not advisable, since the crack was in the bottom of the pipe and would require melting of the joint and rotation of the pipe.

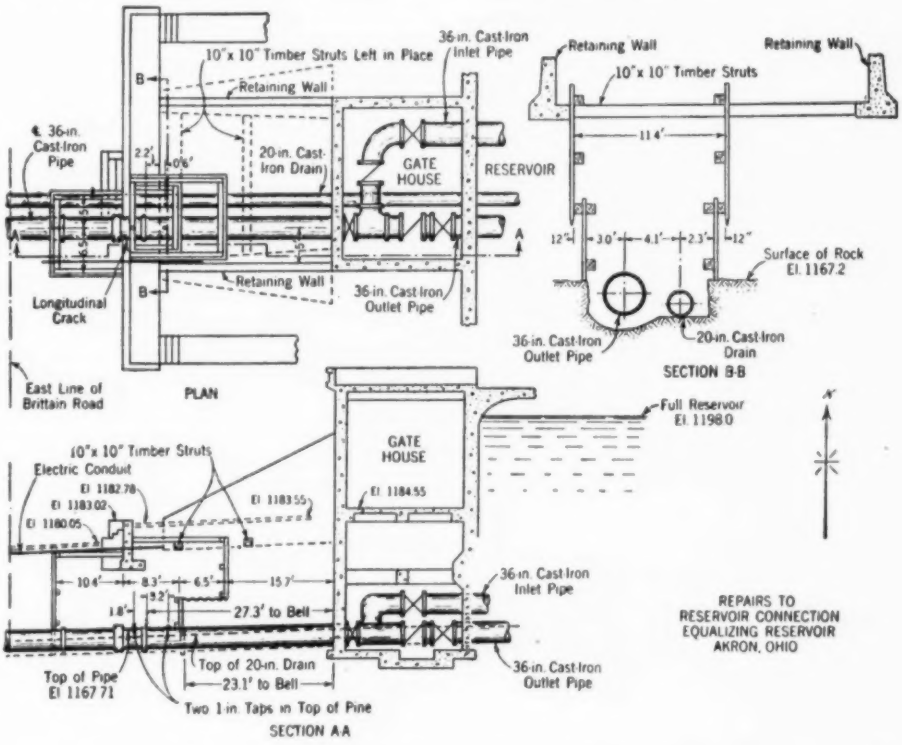
2. Removal of a portion of the pipe and its replacement with a bell-and-spigot piece of pipe and a sleeve. This was adopted.

In order to make the repair, it was necessary to resort to direct pumping. A study of the Saturday and Sunday consumptions for the months of September and October indicated that the pumping station could carry the load without low-lift pumping from about 11:00 P. M. Saturday to 6:00 A. M. Monday. Accordingly, preparations were made to make the repair on the night of October 21 and 22. The pumping station was notified and followed the load curve during the shut-down.

As noted above, the 36-in. pipe was Class A, about 1 in. thick. Much thought had been given to the method of cutting the pipe. A relatively new process of cutting cast-iron pipe with an electric torch was tested at the water works storage yard.

A 36-in. bell-and-spigot piece, with laying length 5 in. shorter than the piece to be cut out of the 36-in. connection, was cut at the yard. This served as a dress rehearsal for the cutters.

The cutting involved a circumferential cut of 10 lin. ft. and a longitudinal cut, including the bell, of 4 ft. The first step was to burn a hole through the pipe at the end of the crack to prevent possible additional cracking due to temperature changes during the cutting. The circumferential cut was then made with two cutters working on opposite sides of the pipe, one cutter working to the top, the other to the bottom. The direction was then reversed, completing the cut. The longitudinal cut was made on top of the pipe, diametrically opposite the crack. The cutting of the bell was done in longitudinal passes, cutting into the bell for its entire length rather than attempting to cut through the bell at one time. The dross dropping into the pipe was porous and easily removed. The cut averaged ½ in. in width and the edges were clean and very true to line. Considerable thought was given to the marking of the line so that it could easily be seen through the colored shields worn by the cutters. The line was marked with a chisel and the chisel markings were connected with white chalk.



Two truck-mounted generators with automatic voltage regulators were used to supply the current for the cutting torches. In cutting the pipe 300 amp. were used. This was increased to 350 amp. when cutting the bell. About 31 lb. of "Fleetweld," $\frac{3}{16}$-in. No. 5 coated rod were used for the 14 lin. ft. of cutting.

When the cutting was completed, wedges were driven into the longitudinal cut, splitting the pipe cleanly along the crack at the bottom. The old pipe was removed and the repair was completed with a bell-and-spigot piece and a solid sleeve. The joints were of lead substitute and braided hemp.

The shut-off was started at 8:00 P. M., and the line was down and drained by 10:00 P. M. Several valves, which were not seriously affecting distribution system pressure, were closed in advance of the actual shut-down. Cutting was started at 11:30 P. M. and completed at 2:00 A. M. The pipe repair was completed by 6:00 A. M. and by 6:30 A. M. the reservoir was back in service.

*From the *Jour. Amer. W. W. Assn.*, March, 1946. Reprinted by permission of the A.W.W.A.

WATER REQUIREMENTS*

Volume Demand and Rates of Flow for Various Uses and Fixtures

Twenty gallons per capita daily is generally conceded to be the absolute minimum quantity of water needed to carry out, properly, the various functions of life of those served a supply of water piped into the property.

The basis for such a per user estimate is the following:

Drinking	1 gal.
Laundry	6 "
Bathing	5 "
Toilet (2 flushes)	5 "

(Possibly the item "Drinking" includes all water used in the kitchen. However, nothing is shown for scrubbing and other miscellaneous uses. So it is apparent that the average per user requirement should be at least 25 gallons and the *reasonable* minimum probably more nearly 30 gallons. In fact, surveys have revealed such to be the case.)

In an A.W.W.A. review of water consumption data the following procedure in estimating appears.*

"For purposes of estimating the probable use of water in a given building the engineer considers those quantities which are used for specific domestic operations and which do not vary appreciably with size of family, as well as the basic consumption rate of 20 gallons per capita per day. The total amount of water used in sprinkling a lawn does not vary with the number of persons living in a given house, nor does the quantity used for washing the family car. On the other hand, the use of water for personal bathing is directly related to the number of persons in the household.

"The figures which are presented here are subject to some variation but they may well serve as an index of the amounts which may reasonably be considered to be used in carrying out various domestic operations. Studies here and abroad have indicated that about one-half to two-thirds of the water used in ordinary household consumption is heated (bathing, laundering, dishwashing, etc.)."

Operation	*Quantity-of-Water*
Tub bath	25 gallons/bath
Shower bath	5 gallons/min.
Additional toilet flush/person	6 gallons/diem
Sprinkling lawn (⅝-inch hose)	7 gallons/min.
Washing automobile	150 gallons
Basic quantity/person	20 gallons/diem

"Two examples will illustrate the use of these data.

Example 1.—A family of five persons is to build a single house on a lot 50 by 100 ft. in a fairly good neighborhood. They plan to have a bathtub and do home laundering, but they have no automobile. How much water per capita (in round numbers) should be estimated as the daily consumption for this family

Basic figure $= 5 \times 20 =$	100 g.p.d.
Lawn watering = 20 min./diem for 3 mos. = 5 min./diem =	35 g.p.d.
Bathing—2 baths/week/person $= 5 \times 50/7$ =	35 g.p.d.
Total =	170 g.p.d.
Per capita consumption =	34 g.p.d.

Example 2.—A family of three is to build a large house on a plot 125 by 250 ft. in an exclusive section of town. Laundering is to be done at home and the two cars probably will be washed twice a month at home. There is a shower for the head of the house, and two baths for the two women. What water consumption per capita could be estimated here?

Basic figure $= 3 \times 20 =$	60 g.p.d.
Additional toilet flushes, $3 \times 6 =$	18 g.p.d.
Lawn watering 1 hour/day for 4 mos. = 20 mins./day for the year =	140 g.p.d.
Bathing—2 baths/day =	50 g.p.d.
Showers—10 min./diem =	50 g.p.d.
Washing cars—600 gal./mo. =	20 g.p.d.
Total	326 g.p.d.
Per capita consumption	109 g.p.d.

Similar methods of approach may be used in solving problems involving large apartments and housing projects."—Jour. A.W.W.A.

In an analysis of available survey statistics from representative cities, essentially, the following conclusions appear in the same article.*

(1) The minimum domestic water requirements for an urban community or household should be assumed at not less than 30 gals./capita/day.

(2) For design of systems, service lines and interior piping it is safer practice in general to use a figure of 40 gals./capita/day.

(3) The increase in consumption can be estimated at a rate of 1% per year, until a maximum of 50 gals./capita/day is reached.

Water Requirements in Various Types of Housing

The following estimates of expected consumption in various types of housing are based on data presented in the same review.

Type of Housing	*Gal./Capita/Day*
Single Family Houses	
Minimum	35
Reasonable	55
Maximum	100+
2, 3 and 4 Family Houses	
Minimum	35
Average	40
Maximum	55
Apartment Houses	
Average	75
Maximum	100+
Housing Projects	
Minimum	35
Reasonable	45**
Maximum	90

RATES OF DRAFT PER FIXTURE OR USE

Individual Needs	Gallons per Day
For all household purposes, including kitchen, laundry, bath, etc.	30
Each cow	10
Each horse	10
Each hog	5
Each sheep	5
Continuous flowing drinking fountains	75

Lawn Fixtures	Gallons per Hour
½-inch hose with nozzle	200
¾-inch hose with nozzle	300
Lawn sprinkler	120
Park or golf course sprinkler covering a 106-ft. diameter area, with ¼-inch main nozzle operating at 50 lbs. nozzle pressure	990

Domestic Fixtures	Gallons
Filling the ordinary lavatory	1½
Filling the average bath tub	30
Flushing water cabinet closet	6
Shower bath	30

(*From, Peerless Pump Bulletin*)

*Based on data and computations in a review of water requirements in "Domestic Water Consumption" Jour. A.W.W.A., December, 1939—by M. A. Pond, and published information from various other sources.

**In measuring the proportion of total consumption that was used as heated water the average was 66%, or 28 gallons in the average total of 42 gallons used per head.

RATES OF FLOW FROM FIXTURES

Fixture	Gallons per Minute† Fair	Good	Excellent
Bath Tubs	5	8	10
Showers (5" to 8" heads)	3	6	8
Lavatory Basins	3	5	8
Laundry Tubs	4	8	10
Sinks (Kitchen & Pantry)	4	8	10
Hose (Sprinkling & Washing)	5	8	10
Toilet Flush (Tank)	2	3	5
Toilet Flush (Flushometer)	20	30	40

†Copper and Brass Research Association figures, supported by other data.

Expected Consumption Rates and Requisite Pipe Sizes in Apartment Buildings

The following tables taken from a bulletin of the Bridgeport Brass Co. indicate expected reasonable rates of draft by apartments of various sizes and number of baths. Also is listed the minimum sizes of service lines and recommended sizes of riser pipes, based on a pressure loss of 10 lbs./100 ft. of run, and terminal fixtures pressure of 15 lbs./sq./in. during water use in all apartments on the same riser, from top floor to ground.

TABLE 1.

RATES OF USE AND DIAMETER OF WATER SUPPLY RISERS FOR APARTMENT HOUSES

(Based Upon 1-2 & 3 Baths per Ap't.)

One (1) Bath Apartment		Two (2) Bath Apartment		Three (3) Bath Apartment	
1 bath	15 gals.	2 baths	24 gals.	3 baths	30 gals.
1 W. C.	8 gals.	2 W. C.	14 gals.	3 W. C.	18 gals.
1 sink	4 gals.	1 sink	4 gals.	1 sink	4 gals.
1 lav.	4 gals.	2 lavs.	6 gals.	3 lavs.	9 gals.
	31 gals.		48 gals.		61 gals.
80% demand, 15 gals. per min.		40%, 20 gals. per min.		40%, 24 gals. per min.	

		RISER		RISER		RISER
Top Floor	15 gals.	1¼"	20 gals.	1¼"	24 gals.	1¼"
Next	28 gals.	1¼"	38 gals.	1½"	43 gals.	2"
Next	38 gals.	1½"	54 gals.	2"	64 gals.	2"
Next	51 gals.	2"	68 gals.	2"	82 gals.	2"
Next	60 gals.	2"	80 gals.	2"	96 gals.	2½"
Next	67 gals.	2"	90 gals.	2"	108 gals.	2½"
Next	71 gals.	2"	98 gals.	2½"	117 gals.	2½"
Next	78 gals.	2"	104 gals.	2½"	124 gals.	2½"
Next	81 gals.	2"	108 gals.	2½"	134 gals.	2½"
Next	83 gals.	2"	110 gals.	2½"	143 gals.	2½"
Next	84 gals.	2"	110 gals.	2½"	143 gals.	2½"
Next	86 gals.	2"	110 gals.	2½"	143 gals.	2½"

TABLE 2.

APARTMENT HOUSE SUPPLY SIZES OF SERVICE LINES FROM MAIN

(Based on Pressure Loss of 10 lbs./100 ft. Run)

For 4 and 5 Stories

No. of Baths	APARTMENTS PER FLOOR Four Gals.	Four Main	Six Gals.	Six Main	Eight Gals.	Eight Main	Ten Gals.	Ten Main
1 bath	120	2½"	160	3"	200	3"	240	3"
2 baths	160	3"	200	3"	240	3"	280	3"
3 baths	200	3"	240	3"	280	3"	320	3½"

For 6, 7 and 8 Stories

No. of Baths	APARTMENTS PER FLOOR Four Gals.	Four Main	Six Gals.	Six Main	Eight Gals.	Eight Main	Ten Gals.	Ten Main
1 bath	150	2½"	190	3"	230	3"	270	3"
2 baths	190	3"	230	3"	270	3"	310	3½"
3 bath	230	3"	270	3"	310	3½"	350	3½"

For 9, 10, 11 and 12 Stories

No. of Baths	APARTMENTS PER FLOOR Four Gals.	Four Main	Six Gals.	Six Main	Eight Gals.	Eight Main	Ten Gals.	Ten Main
1 bath	200	3"	250	3"	300	3½"	350	3½"
2 baths	250	3"	300	3½"	350	3½"	400	3½"
3 baths	300	3½"	350	3½"	400	3½"	450	4"

DELIVERY THROUGH BRASS AND COPPER PIPES OF VARIOUS SIZES FOR VARIOUS PRESSURE DROPS

(Each line being 100 ft. long)

Pressure Drop (Lbs.)	Gallons per Min. Delivery Through ⅜"	½"	¾"	1"	1½"	2"	2½"
5	2	3	7	13	40	80	150
10	3	5	10	20	60	130	225
20	4	7	15	30	90	200	300
30	5	9	20	40	120	250	375

BLOTTING OUT WASTE

Safe Water
delivered night and day
Costs Less
than anything else you buy
· · *but* · ·
Don't Ignore Leaks!

* * *

Satisfied customers are worth more to us than revenue secured from water uselessly passing through meters.

INDIANAPOLIS WATER CO.

What Leaks May Cost

Size of Leak	Gallons per 24 Hours	Gallons per Month	Cost per Month
½"	47,600	1,451,800	$156.21
¼"	12,300	375,150	60.05
⅛"	3,200	97,600	19.65
1/16"	860	26,230	6.35
1/32"	215	6,550	1.97

(Above estimates are based on Indianapolis pressures without allowance for friction loss)

The above is a reproduction of the top side of a little blotter sent out to customers, reminding them of the high cost of allowing fixture leaks to persist. If as good at blotting waste as ink, the scheme is praiseworthy.

Incidentally, the Indianapolis Water Company gets in a good public-relations message about satisfied customers being worth more to them than the added revenue from the uselessly metered wastage.

JOHNS-MANVILLE

Executive Offices: 22 E. 40th Street, New York 16, N. Y.

Offices in all large Cities

●

TRANSITE PRESSURE PIPE

A brief discussion of how this asbestos-cement pipe can help you provide more efficient water service at lower cost—

12 WATER PIPE PROBLEMS AND HOW TRANSITE PIPE HELPS SOLVE THEM

●

TRENCHING COSTS

Trenching costs are low with Transite. No bell holes are required at the joints, and the width of trenches and disturbance to pavement are kept to a minimum.

HANDLING COSTS

Transite's light weight means more footage per truck load—easier handling at the trench.

INSTALLATION COSTS

Fast assembly with the Simplex Couplings keeps installation costs low, minimizes traffic tie-ups.

CURVES

Transite's flexible Simplex Couplings permit deflections up to 5° at each joint without use of fittings.

JOINT LEAKAGE

Tight, flexible Simplex Couplings guard against costly underground leakage and washing away of supporting soil and undermining of the pipe.

RED WATER

Made of asbestos and cement, Transite Pipe cannot rust—cannot cause red water.

ELECTROLYSIS

Stray electric currents from power lines cannot damage this non-metallic pipe.

VIBRATION

Transite's flexible joints absorb the vibration of heavy traffic—stay tight in service.

SOIL STRESSES

Major factors assuring high resistance to soil stresses are Transite's high uniform strength, its exceptional resistance to corrosion, and tight Simplex Couplings.

SOIL CORROSION

Hundreds of installations in aggressive soils prove Transite's high corrosion resistance.

DELIVERY CAPACITY

Tuberculation cannot reduce Transite's high delivery capacity (C = 140). Therefore, pumping costs stay low.

MAINTENANCE

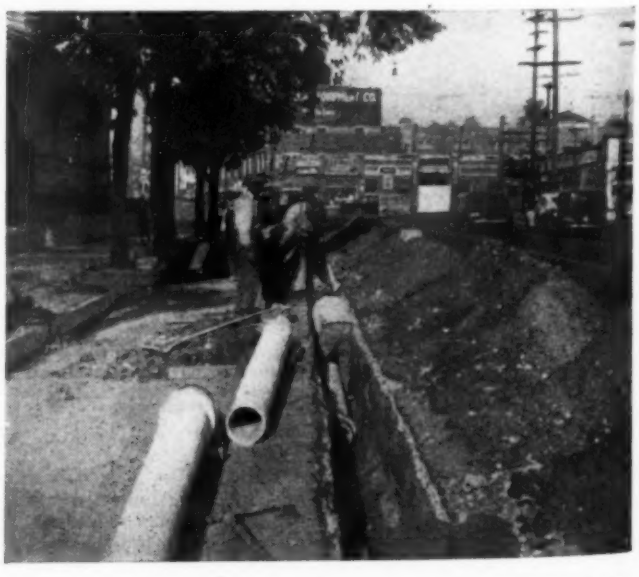
Because of its corrosion resistance and tight joints, maintenance costs are kept low.

IN SELECTING a pipe for water lines—whether for the extension or replacement of existing lines or the installation of a complete new system—careful consideration should be given to the basic factors contributing to the economic life of the pipe. For example:

DELIVERY CAPACITY . . .

Waterworks engineers generally agree that a water main, even though it remain structurally intact, may outlive its economic usefulness over a period of time. This points is reached when the pipe will no longer carry, economically, a sufficient volume of water to meet demand. Such a condition may arise from characteristics inherent in the pipe itself, from increased demand on its delivery capacity, or from a combination of these two causes. Therefore, in designing water systems, the engineer is faced with the responsibility of anticipating and solving these problems.

To compensate for expected reductions in carrying capacity, specifications often call for larger sizes of pipe than would otherwise be necessary. However, there is another, more



One of thousands of municipalities where Transite Pipe is contributing to efficent, economical water service. Transite's speed of assembly reduces the time trenches must be open—minimizes traffic congestion and inconvenience to business.

JOHNS-MANVILLE

No bell holes are required at the joints and width of trenches is kept to a minimum when Transite Pressure Pipe is installed.

For economical and efficient water supply and distribution lines, thousands of American Communities are using Johns-Manville Transite Pressure Pipe.

fundamentally sound solution. In J-M Transite Pipe, engineers find basic advantages that permit them to specify the most economical pipe sizes with full assurance that delivery capacity will never be reduced by tuberculation, the internal corrosion which, even when present in relatively small degree, greatly reduces carrying capacity.

Transite Pipe is an asbestos-cement product. During manufacture, it is built up on a polished steel mandrel that imparts unusual smoothness to the interior wall. Its flow coefficient is conservatively established at C = 140, which provides an exceptionally high carrying capacity.

Transite's freedom from tuberculation means that pressures need not be increased, mains periodically cleaned or systems reinforced with larger or additional mains to compensate for a steadily decreasing flow coefficient arising from this costly form of internal corrosion. Furthermore, in many cases Transite Pipe permits the use of smaller diameter pipe with resultant savings in all the numerous items that go to make up the original cost of a completed water line.

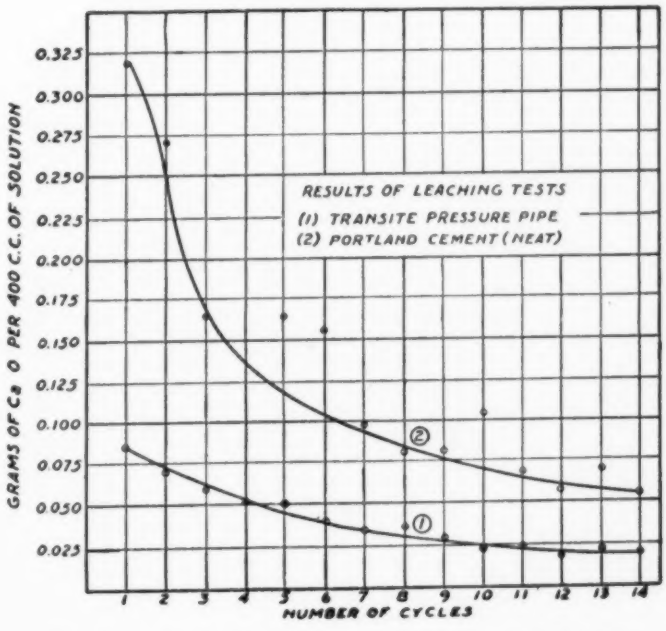
SOIL CORROSION . . .

Broadly speaking, most soil corrosion engineers agree that there are two principal forms of soil corrosion — chemical and electro-chemical.

Chemical corrosion is caused by the direct, corrosive action of acids and salts encountered in the soil. Transite Pipe, due to a special process of manufacture and treatment, is virtually inert to concentrations of acids and salts ordinarily found in soils. Free lime which might generally be expected in cement products, has been largely converted to insoluble silicates due to the method of manufacture. A comparison of the two curves in the diagram below shows the high degree of insolubility of Johns-Manville Transite Pipe. It is for this reason that Transite is so resistant to the forms of chemical corrosion as encountered in soils.

Electro-chemical corrosion is caused by the electrolytic action between ordinary pipe and substances in the soil. This action is similar to that of a simple electric cell. In this case, the substances in the soil represent the positive pole; the soil moisture, the electrolyte, and the pipe wall serves as the negative pole. The current generated passes from the pipe to the positive pole and causes a gradual disintegration of the pipe structure.

With Transite, however, this condition can never



The chart above represents a series of leaching cycles for both pulverized Transite Pipe and neat cement. The small amount of free lime extracted from Transite indicates that for all practical purposes it may be considered insoluble—one of the major factors responsible for its unusual resistance to soil corrosion.

JOHNS-MANVILLE

occur, because being non-metallic, Transite is a non-conductor—therefore absolutely free from electrochemical corrosion. Furthermore, this asbestos-cement pipe is immune to electrolysis caused by stray electric currents from high voltage lines, street railways, etc.

The successful performance of thousands of Transite Pipe installations in all kinds of soil and under many varying climatic conditions provides practical proof of its high resistance to corrosion—inside, outside, and all the way through.

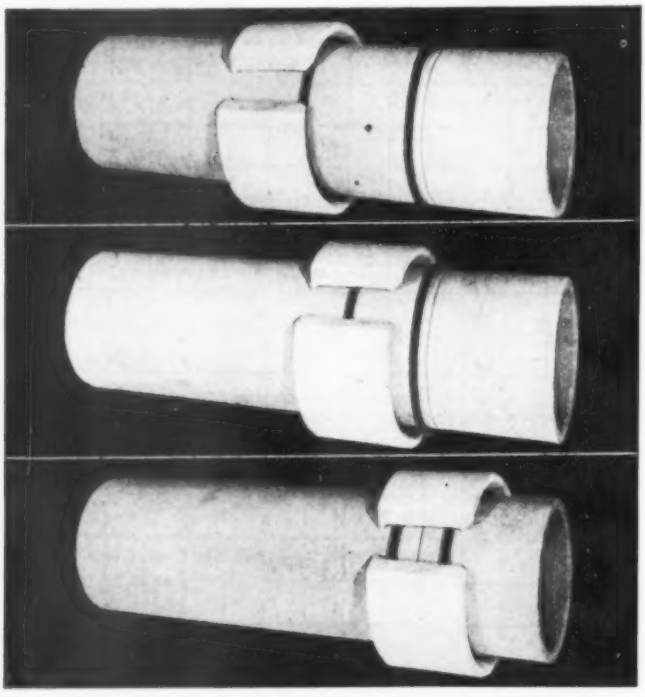
JOINT LEAKAGE . . .

Numerous surveys have shown that leaky joints are responsible for a considerable portion of total water losses from underground mains. Generally recognized by waterworks men as a serious problem, joint leakage not only results in a direct waste of water, but, by washing away supporting soil, contributes to failure of lines under traffic and earth loads.

Much of this trouble is caused by the fact that the ordinary rigid joint, even though initially tight, may open up when subjected to vibration or settlement after the line is in service.

Such potential losses are minimized with a flexible joint. And that is the principle upon which the Simplex Coupling, employed in assembling Transite Pipe, was designed. Consisting of a Transite sleeve and two rubber rings, it forms a tight joint that stays tight in service. Its flexibility guards against vibration and stresses transmitted by the soil. Depending upon the size of the pipe, a deflection of as much as 5° is possible at each joint.

The ease of assembling the Simplex Coupling and its dependability in service is due primarily to these distinctive features:



Cut-away views showing the simple assembly of the Simplex Coupling. Top: Rubber rings and sleeve at start of assembly. Center: Sleve pulled over one rubber ring. Bottom: Final position, sleeve centered over joint.

Made of asbestos and cement, Transite Pipe is uniformly strong and durable . . . withstands the vibration of heavy traffic and soil stresses.

1. It is actually a pre-fabricated, "packaged" joint. The ends of each pipe and the inside of each coupling are machined to specific dimensions. The rubber rings are precision-made and subjected to rigid inspection before shipment. Joints are assembled cold—no pouring, caulking or heating equipment is used. A simple coupling, puller, available from Johns-Manville, is the only tool required for assembly.

2. The effectiveness of the joint does not depend on the individual skill or training of the workmen. So simple is the operation that perfect Simplex joints can be made quickly and economically even by unskilled crews.

The Transite sleeve, like the pipe itself, is made of asbestos and cement and has the same high degree of resistance to corrosion. The rings, made of the highest quality rubber, are carefully cured and specially compounded with anti-oxidents and properly graded non-hygroscopic fillers to assure permanence in water service. Thousands of installations testify to their dependability and permanence.

INSTALLATION . . .

One of the major factors contributing to initial cost of a pipe line is the time and equipment required for installation.

Transite Pressure Pipe offers primary advantages that help speed up installation and cut costs. The long, 13-ft. lengths are relatively light in weight. Two or three men can easily lower 8 inch pipe into the trench by hand. In fact, all but the largest sizes can be handled without the use of mechanical equipment.

Simplex Couplings are assembled cold just as they are received from the factory. Wet trenches present no problem. Assembly of the line is completed with savings in time and man hours of labor expended.

WRITE FOR COMPLETE DETAILS

A detailed discussion of the economic factors contributing to efficient low-cost water lines is given in the Transite Pressure Pipe Brochure, TR-11A. The 76-page "J-M Pipe Installation Manual," D. S. 332, outlines effective methods of installing water lines and includes much more data on Transite Pipe and the Simplex Coupling than was possible to include on these pages. For your free copy of these books write to Johns-Manville, Box 290, New York 16, N. Y.

JOHNS-MANVILLE

Executive Offices: 22 E. 40th Street, New York 16, N. Y.

TRANSITE SEWER PIPE

IN YOUR SEWAGE DISPOSAL SYSTEMS - - -

Some fundamental advantages of Transite Sewer Pipe that help reduce the cost of sewer line construction, maintenance and operation.

TRANSITE SEWER PIPE

Gravity Sewer Lines offer a number of specialized problems which Transite Sewer Pipe meets eminently well. For example:

INFILTRATION—

It has been authoritatively estimated that as much as 25% of the contents of the average sewer is ordinary ground water that enters the system by infiltration through the joints. And it costs practically as much to treat this water at the disposal plant as it does to treat sewage itself, thereby increasing operating costs and hastening the day when plant facilities may have to be expanded to provide for increased load resulting from a normal population growth. Furthermore, in many cases engineers must allow for this huge quantity of water by specifying a larger diameter pipe than would otherwise be necessary.

With Transite Sewer Pipe, however, the infiltration of ground water presents no serious problem. Transite's long 13-ft. lengths cut down the number of joints in the line, thus reducing the danger of infiltration right at the start. Furthermore, the sleeve type joints employed in Transite lines are unusually tight and stay tight in service. The joint is strong, flexible and highly resistant to cracking or shrinkage stresses. As a result, Transite Sewer Pipe installations have shown far less infiltration than that allowed by the usual specifications.

CARRYING CAPACITY

One of the most important factors in any sewer line is carrying capacity. All other things being equal, the relative carrying capacity of two or more types of pipe is best indicated by their flow coefficients. If, for example, the inside of the pipe is rough and uneven, the flow velocity and carrying capacity are greatly reduced. A smooth pipe provides a higher flow velocity and a correspondingly higher carrying capacity.

Transite Sewer Pipe has an unusually smooth interior surface, its conservative friction coefficient being $n = .010$. The resulting high carrying capacity means savings that can be taken in one of two ways. Flatter grades may be employed during installation—reducing the depth of the trench, and therefore cutting down on the amount of excavation required, and making installation a faster, more economical job. Or, when a steeper sewer pipe grade is employed and deeper trenches excavated, Transite's higher flow velocity often makes it possible to use a smaller diameter pipe without reducing the desired carrying capacity of the system.

Transite, the corrosion-resistant, asbestos-cement sewer pipe, answers every requirement of efficient sewerage service. Its long 13-ft lengths make laying to exact grades a quicker and more accurate job. And the tight joints employed minimize inflation.

OTHER CONSIDERATIONS

Resistance to corrosion, structural strength, and ease of installation are, of course, other important considerations in the selection of sewer pipe.

Because of its special asbestos-cement composition and its unusually low free lime content, Transite Sewer Pipe is highly resistant to the corrosive action of all types of domestic sewage and most industrial wastes—inside, outside and all the way through.

Transite Sewer Pipe is furnished in sizes from 4″ to 36″ in Class I, from 10″ to 36″ in Classes II and III, and from 18″ to 36″ in Class IV. Each class of pipe is made to specific crushing strengths, thereby providing for the selection of the most economical combination of classes of pipe to meet the specific strength requirements of the line and eliminating the need for concrete cradling.

The long 13-ft. sections in which Transite is furnished eliminates many of the problems encountered in the installation of short length sewer pipe. Relatively light in weight, these long lengths cut down handling costs. More footage may be carried per truck load to the trench and fewer man-hours of labor are needed to install the pipe. These long lengths also reduce the number of joints that must be made and thus save considerable time and labor. In addition, long lengths greatly facilitate laying the pipe and maintaining the line to an accurate grade.

TRANSITE PRESSURE PIPE FOR SEWER LINES

Operational requirements of pressure sewer lines are very similar to those of water lines. In addition, the pipe must be resistant to the corrosive action of the sewage. Transite Pressure Pipe for sewer lines, which is made of the same durable asbestos-cement composition as Transite Water Pipe, described on the preceding pages, meets all these requirements and provides highly satisfactory service in systems of this type as demonstrated in numerous installations.

For further details on Transite Sewer Pipe for gravity lines, write Johns-Manville, 22 East 40th St., New York 16, N. Y., for Brochure TR-21A; on Transite Pressure Pipe for force mains, write for TR-11A.

AMERICAN HARD RUBBER COMPANY

11 MERCER STREET, NEW YORK 13, N. Y.
Representative: 111 W. Washington St., Chicago 5, Ill.; Akron 4, Ohio

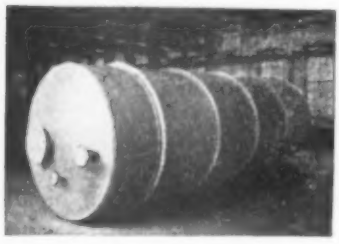
Ace Rubber Protected Equipment for Water Purification and Sewage Disposal Plants

ACE HARD RUBBER AND ACE RUBBER LINED EQUIPMENT

Handles all phases of storage, pumping and piping problems in connection with ferric chloride and chlorine water treatment and sewage disposal. Ace hard rubber is chemically inert and resistant to the action of most acids and corrosive solutions. It prevents corrosion and rust contamination in many types of equipment. Ace rubber linings are tough, strongly bonded specially reinforced where necessary, and high voltage tested to insure perfection.

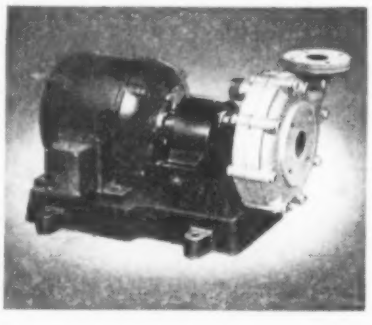
CHEMICAL MIXING AND STORAGE TANKS

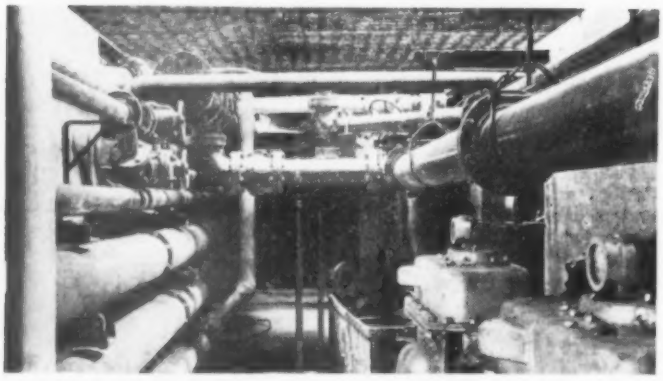
All sizes and shapes of tanks, thoroughly protected by Ace hard rubber linings so that no metal parts come in contact with corrosive solutions. Complete tanks available, or Ace protective linings applied to tanks furnished by the customer. Also rubber covered and rubber lined filters and other special equipment.



ACE RUBBER-PROTECTED PUMPS

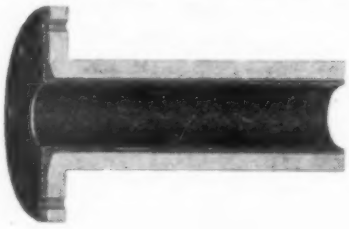
Made in several sizes and types, with some parts made of solid Ace hard rubber, and other parts lined with Ace rubber for adequate corrosion resistance. Ace Type W.A.M. centrifugal pump illustrated, for medium capacities up to 90 g.p.m. at 12 ft. head. Excellent for pumping all water-treating chemicals. Ace pumps with capacities up to 300 g.p.m. at 40 ft. head also available.





In this sewage installation, Ace hard rubber lined pipe, valves, fittings; Ace solid hard rubber pipe and fittings, and an Ace rubber-lined tank were used for maximum corrosion resistance.

ACE RUBBER-LINED PIPE & FITTINGS



Combines strength of steel and acid resistance of Ace rubber linings. Fully protected through pipe and over flange faces. Hard or soft rubber linings as required. All flanged, in sizes from 1½ in. up.

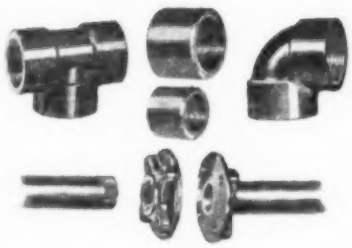
ACE HARD RUBBER PIPE & FITTINGS

Solid hard rubber pipe available in sizes from ½" to 8" inclusive. Ace solid hard rubber flanged and threaded pipe fittings available in all sizes and types for permanent chemical-handling lines.

ACE SARAN PIPE, FITTINGS AND MOLDED PARTS

Chemically resistant, strong plastic available from Ace in pipe sizes from ½" to 4", with standard Ace Saran fittings from ½" to 2". Easily butt-welded with heat. Special molded parts available.

Write for Ace Saran Bulletin.



ACE RUBBER LINED VALVES

GATE VALVES, hard rubber lined available in sizes 2" to 12" inclusive except 2½" size.

DARLING GATE VALVES, hard rubber lined, with special metal trim for the required service. In sizes 2" to 20" inclusive.

DARLING CHECK VALVES, non-slam, for vertical or horizontal operation. Sizes 2" to 12" with internal special chemical-resisting metal parts.

DIAPHRAGM VALVES, rubber lined, sizes from 1" to 6" inclusive. (Hills-McCanna Co., Saunder Patent.)

64 PAGE CATALOG ➡

Covering all types of Ace Rubber Protected Equipment, available upon request. You'll want this reference when specifying maximum corrosion resistance and *longer* equipment life with Ace protection. Write also for the Ace Saran pipe and fittings bulletin.

BLOWING OUT SERVICE LINES

By S. H. DAVIS

Superintendent, Benwood & McMechen Water Co.
Benwood, W. Va.

Most every water works operator will agree that a low pressure complaint can cause a water company to have poor, or at least "razor-edged," public relations between the affected customer and the company.

However, unless the condition is caused by insufficient main line capacity, the consumer's line, as well as the company's service line, is usually the cause of the low pressure complaint. Attempts to convince the affected customer that he should renew his lines usually brings the following question or statement: "Suppose I do renew my lines, maybe your line is stopped up between the main line and my property. How about you people doing a little digging first?" To answer that question to his satisfaction, usually means to remove meter, if located at property line or curb plot, or cut service line at curb-stop, and let him see for himself. If the pressure is poor and he sees it, he becomes very positive that he won't spend a dime until given better water pressure. He thinks it is high time that the water company correct that condition and he wants it done *"right now."*

Naturally, anyone responsible for the operation of a water company wants the customers satisfied, but on the other hand, he hates to dig into a paved street to disconnect a service from the corporation, or to renew the service line to satisfy the customer.

Method of Cleaning

We have had the usual number of low pressure complaints with all the grief that goes with them. We have tried various methods of cleaning out service lines and the method we now use is the compressed air and rock salt method.

The equipment consists of the following parts:

(1) Cylinder of compressed air—*don't use oxygen.*
(2) 15 ft. (2,000-lb.) wire braided hose with suitable connections to connect to service line.
(3) 1 (2,000-lb working pressure) check valve.
(4) 1 (2,000-lb.) working pressure) forged cross tee.
(5) 1 (2,000-lb. working pressure) angle valve—wheel type.
(6) 1 (1,000-lb.) relief valve—set at 600 to 800 lbs.
(7) 1 (1,800-lb.) pressure gauge.
(8) Necessary nipples to connect fittings and for connections on air cylinder (use extra heavy nipples).

The method of blowing out service lines is as follows:

(1) Make necessary test for low pressure.
(2) Fill wire braided hose with about 2 ft. of coarse rock salt (ice cream salt) and connect to service line with curb or meter stop in the off position.
(3) Close angle valve on tank connection—hose.
(4) Open curb or meter stop.
(5) Just crack needle valve on compressed air tank and then close *quickly* with one hand.
(6) Open angle valve *immediately* with other hand—the "shot" is fired.
(7) Allow muddy water from service to blow through angle valve until water is clear.
(8) Connect up line.

It is advisable to "crack" a nearby fire plug so that the excess air will go out through plug.

The action of the compressed air is very quick and a surging will be noticed in the armored wire hose, but after a few seconds the surging will stop and the water will flow out of the angle valve with normal pressure. As the rock salt enters the service line it literally scrapes the incrustation away from the line and the rock salt dissolves in the main line. No complaint of salty taste in the water has resulted, however.

This system is only recommended where lead or copper service lines have been installed. There is too much danger of rupturing a weakened steel line which is badly corroded.

The photographs show the results of this method. The height of water above ½-inch riser pipe (30 in. above curb stop) was 3 in. only. But, after blowing out service line the height of water was 36 in., indicating increased pressure and volume obtained.

We have found that after we do our part, should the pressure continue low, consumers become convinced that their piping is either corroded or too small. In most cases they will remedy their condition. We do not blow service lines from cellar to property line, because we feel that is the plumber's job.

The average time required to attach the equipment and blow out a service line is only 15 minutes. Our cost for a cylinder of air is approximately $2.50.

Dribble *Load* *Shoot* *Gush*

One That Needs Blowing; Loading Armored Hose with 2 ft. of Rock Salt; the Quick Shot of Compressed Air (Note Man with One Hand on Cylinder Valve, the Other on Release Angle Valve). Results—Plenty of Water and a Satisfied Customer.

PROTECTING WATER PIPES FROM FROST

By F. J. RENY
Treasurer and General Manager
Portland Water District
Portland Water District

IT IS probable that the first attempt to protect water pipes in a dwelling house from freezing was to allow the water to run to waste. Of course, this method of protecting water pipes is abhorrent to the water works manager and he will find some method to prevent this waste unless he has all the water in the world to run to waste and he figures that it does not cost him anything.

Protecting Meters

Experiences with installations have led to various methods of protection, one being the setting of the meter in the basement and building a wooden box around it, about 18 inches square, and the box being packed with sawdust or some other dry material which will keep the frost out. Others use a "meter-mitten," so-called, which is made of some fibre preparation and is the shape of a meter and can be put around the meter itself, leaving an air space by way of protection. I have never heard that these were successful however. The installation of the meter in a pit outside is usually too expensive, unless it is the only way to install the meter to cover the use in the building.

Our experience with meter pits in the ground outside of the building involves those built of 2-inch hemlock plank nailed together with heavy spikes and heavy cleats to form the four sides of the pit. The bottom is about 4 feet square and the top large enough to fit the iron frame, which is 24x29½ inches and contains a round cover 15 inches in diameter. These can be installed in the usual dirt street or sidewalk for about $35 and they give as little trouble as anything that has yet been devised. Smaller pits have been made of tile and other material but they are not sufficiently frost-proof for our conditions.

In some sections where buildings are set on posts and must be metered we have placed the meter in the kitchen, where heat from the range protected it from frost.

Some have found that where heat is not available in the basement that on cold nights a lighted lantern will generate heat enough, if it is placed close to the meter, to prevent freezing of the meter.

Protecting Service Lines

The following are some of the rather common methods of protecting house services where buildings are not modern and the cellars are not heated with modern ranges or boilers. The most efficient method of protecting a house service, however, is sufficient cover to prevent the penetration of frost to the depth of the pipe. Experiments have proved that services which are laid with at least 5-foot cover are mostly always sufficient unless there is an unusual winter with a long spell of sub-zero weather and with very little snow cover. The lack of the snow blanket results in greater frost penetration and over a short time. We are laying all new water pipes five and one-half feet deep, which seems to be a safe depth.

Pipe Insulating

Many kinds of insulations have been tried by water works to insulate services where sufficient cover could not be obtained and where expensive ledge excavation made the cost very high and it was a question as to whether it would cost less to insulate them or blow out the ledge. I confess that our experience in most cases has been that there is no substitute for installing the pipe below the frost line in the beginning, and many have found to their sorrow that a pipe insufficiently covered is going to give them trouble, and when they awake some cold morning and find the service frozen, they will then have to go to the expense of lowering the pipe to the proper depth. Ledge excavation is no longer the costly job that it used to be, and some local contractors will take out ledge for as low as 75c per foot with their own machinery.

The greatest hazard that we have found in winter time is around the salt water and the wharves. Most of these places are business houses, and where small amounts of water are used and where they cannot afford to pay for water wasted to prevent freezing, and some method must be found so that they can shut off the water at night and drain their service in order to avoid a freeze-up.

A rubber insulation was devised for copper service and tried out by us on several water front locations. Thus far, the rubber covered services have not given us any trouble. Several installations were put in filling stations and in churches where services were held in the church only once a week and where there was no heat during the week. The rubber insulation has served in these cases without giving any complaint.

What a Piece of Plank Will Do

Perhaps the most common form of insulation of water service that has been tried is the method used by the farmer who laid his pipe from the spring to his dwelling house not covered to sufficient depth and in order to avoid freezing he took an ordinary board and placed it on the pipe in the trench and filled in the earth around it. Investigation of this method has proved that the frost will not go through the wooden board and the board will stay a good many years before it rots underground and allows the pipe to be reached by frost. I have seen spring pipes which have been in the ground thirty or more years and with a covering of not more than 2 ft. 6 in., and yet the pipe had never frozen. The board seems to divide the frost when it strikes and the frost goes down on either side. Investigation of this method has shown us that worms will live under the boards through the winter.

Other forms of protection have been tried such as pipe covering or enclosing the pipe in a metal or tile conduit with an air space so that if freezing should occur, it can be disconnected and pulled out, but these are very much more expensive than the simple method of the wooden board. So much for services.

Protection for Mains

In regard to the protection of mains, many interesting experiences can be told about the protection of mains from frost. Most of us have seen water mains which have sufficient pressure and velocity exposed to the air all the year round with no danger of freezing whatsoever, because of the high rate of flow. We have in our Portland system pipe lines where the tops of the pipes are exposed but they have never been frozen. Perhaps the most exposed place in water mains is on bridge crossings where the flow through the night is less and the water in the pipe would be liable to freeze. In many cases, bridge crossings have been insulated in the following manner. A crew recaulks all of the joints to see that they were absolutely tight. Then a heavy coating of ¾ in. felt is wrapped around the pipe and held in place by copper wire. On top of this wrapping of felt there is another wrapping of ordinary 2-ply roofing paper which was also wound with copper wire. Care is taken all the time to break joints so that dampness cannot get in. Another wrapping of felt is then placed about the pipe over the roofing paper and another additional wrapping of roofing paper over this second coating of felt. A copper wire is then wound around the pipe so that the wrappings are about 3 inches apart and then all exposed or open places carefully covered with roofing cement. The entrances of the pipe line into the dirt or stone are also caulked in order to protect them as far as possible. Thus far the bridge crossings which we have insulated in this manner have never given us any trouble.

Water Warming

Perhaps the most interesting experiment in protecting a submarine line was performed by the Casco Bay Light and Water Company of Portland, Me. They send water through a 6-in. line from one island to another, and it was found that the temperature of the sea around the fresh water in the pipe would cause it to freeze because fresh water has a higher freezing point than salt water and therefore it was decided by the Casco Bay Company to slightly preheat the water with an electric heater before it started on its journey through the submarine line to the island, some 2,000 or 3,000 feet away. This experiment was very successfully accomplished.

The protection of water mains from freezing most always brings up the additional question of the protecting of submarine lines and it has been our experience in all cases that submarine lines should be laid in a trench and buried with sufficient cover to avoid the action of the cold salt water.

ELECTRONIC PIPE FINDING AND LEAK LOCATING*

By CURT R. FISHER
Fisher Research Lab., Palo Alto, Calif.

SINCE the war, much of the new knowledge in the field of electronics has become available to utilities. Just as radar was used to detect a plane or ship and sonic locators were used to detect the fine vibrations of a submarine, so, now, the same electronic principles have been applied at the Fisher Research Laboratory,

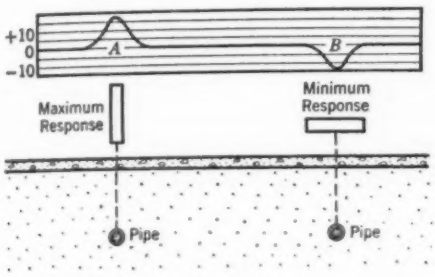


Fig. 1. Operation of Pipe Finder

Palo Alto, Calif., to produce instruments that locate pipe and detect leaks. Pipe finding and leak locating are complementary; the pipe must be found before the leak can be discovered. It is, therefore, logical to describe the job in two phases: first, that of finding the pipe, and, second, that of finding the actual leak.

Pipe Finding

The finding of the pipe is done with an electronic device known as the "M-Scope Pipe Finder." This equipment consists of a directional transmitter, a directional receiver, a pair of long handles, a pair of phones and a carrying case.

The operation of the pipe finder is very simple. There are two directional loops, one with the transmitter, the other with the receiver. If both loops are held in a vertical position over a pipeline, as in "A" of Fig. 1, maximum response is shown on the meter, and the tone in the earphones is loud. If the transmitter is in a vertical position and the receiver horizontal over the pipe, as in "B" of Fig. 1, the response will be at a minimum. If the receiver is moved slightly from side to side, the response will increase on either side of the center of the pipe.

With both the transmitter and receiver vertical and approximately parallel to, but not near, the pipe, the response in the receiver will be very low. When both operators are directly over the pipe, a maximum response will be obtained both in the phones and on the visual meter of the receiver. In this manner, almost any pipe can be located easily and accurately. In all these operations, however, the two units must be kept at least 30 ft. apart, lest they couple directly through the air.

Pipe Center and Depth

To locate the exact center of the pipe, the receiver need only be moved horizontally over the pipe with the transmitter still vertical. There will be a null or minimum response in the phone when the receiver is exactly over the center. A slight increase will be noted on either side of the null point as the receiver is moved from side to side. After finding the exact center of the pipe, its depth can be determined readily.

With the transmitter still vertical over the pipe at "A" (Fig. 2), the receiver should be moved away in a line perpendicular to the pipe, but with the receiver case tilted in a 45-deg. angle until, at "B," a null position is found again. From this point, "B," the distance to "A," the center of the pipe, as obtained by the null in the horizontal position, equals the distance downward from "A" to the pipe. What has happened is that use has been made of the equality of the arms of the isosceles right triangle BAC that was formed.

Bends, Dead Ends and Services

To locate a bend in a pipe, the receiver need only be placed over a known portion of the pipe and the transmitter moved along the pipe as in locating it originally. If the pipe bends, the response in the receiver will drop off at the bend. The searcher should then move in a circle, pointing the transmitter toward the spot where the last definite indication was obtained. The direction of the bend will be revealed as soon as the exploring transmitter crosses it.

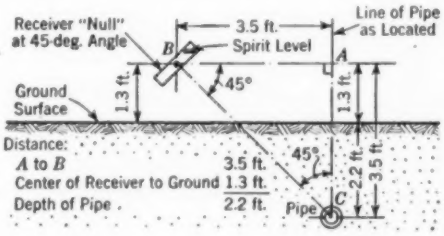


Fig. 2. Determination of Depth

Dead ends can be located in similar fashion. With the receiver over the known part of the pipe, as before, the transmitter is moved along the pipe until a sudden drop of response indicates the dead end.

With the receiver still vertical over a known portion of pipe, a stub or service may be located by moving the transmitter vertically but in a 90-deg. angle to the main. As the transmitter passes over the lateral, a response will be obtained in the receiver.

Detection of Metal Objects

To locate metal objects, valves or valve and manhole covers, the receiver and transmitter should be coupled with the pair of handles. As shown in Fig. 3, the two units are then neutral to each other. A control is provided on the transmitter to obtain a

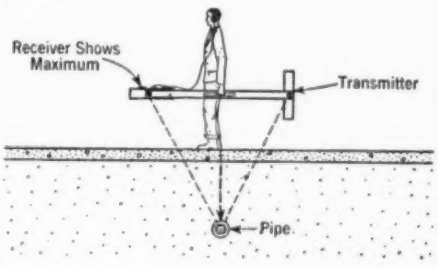


Fig. 3. Detection of Metal Objects

perfect neutral position. When the equipment is operated in this manner, it will indicate the presence of metal objects when passing directly over them. This procedure may be used to locate obstructions in the path of a ditch digger. It is a widely used method and has saved the great expense of repairing broken pipes and cables.

Leak Location

The leak locator is known as the "M-Scope Water Leak Detector." As it is a very sensitive instrument, it must always be handled with care. In operation, vibrations from a leak are picked up with a sensitive crystal pickup, translated into electrical currents and amplified in a high-grain amplifier as much as 10,000 times. The instrument is equipped with headphones and a visual indicator which records the leak vibrations.

To use the detector, the line of the pipe must first be determined and its location marked on the surface. The detector should then be connected, and the pickup unit attached to the pickup plate and placed directly at the line on the pavement. A reading may then be taken from the meter.

By advancing the pickup unit to other stations, and watching for the highest reading, the general location of the leak may be found. Its precise location may be fixed

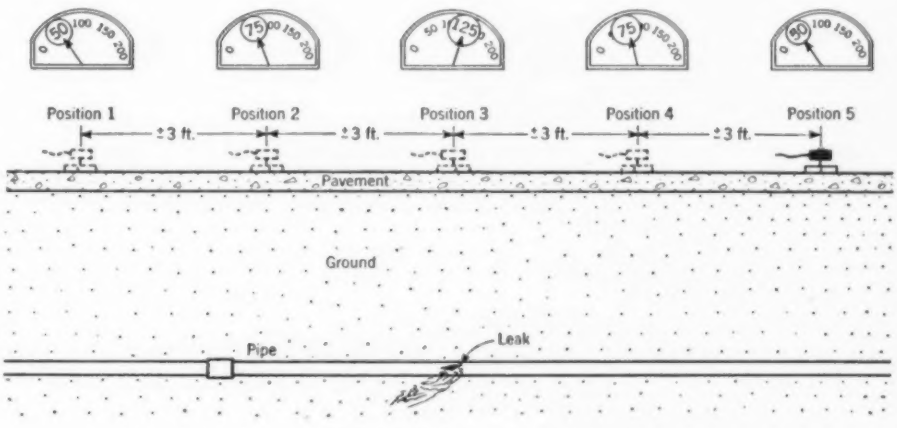


Fig. 4. Meter Readings for Leak Location

*From the *Jour. Amer. W. W. Assn.*, Dec., 1946. Reprinted by permission of A.W.W.A.

Fig. 5. Leak Location by Contact

by the highest of the readings taken when moving in short intervals of about 3 to 6 ft. (Fig. 4). Care must be taken not to touch the pickup during a reading, lest the unit be disturbed.

Contact Leak Location

If this procedure does not give the desired results, the contact method should be used. For this, it is necessary to make direct contact with the pipe in order to obtain readings on exposed connections such as meters, valves, hydrants or actual exposures of the pipe (Fig. 5).

The test should start at the meter box nearest the visible water indication. With the pickup unit resting on the meter or pipe (not held by hand), a reading is taken. The pickup unit should then be moved to the adjacent meter boxes and the procedure repeated. The highest reading will be at the box nearest the actual leak.

It is possible to be misled by water being drawn through a pipe. Recording gears moving in the meter will cause a reading; it may therefore be necessary to shut down service temporarily.

When a maximum is obtained on one meter, the main and lateral should be checked with the non-contact method. If the leak is still not found, the main may be contacted in the vicinity where the highest reading was obtained by drilling contact holes through the pavement.

With the sounding rod touching the pipe at "A" (Fig. 6), the pickup should be attached and a reading taken. A second hole "B" should be drilled and the procedure repeated. If the reading is less at "B," a third hole "C" will have to be tested in the opposite direction, and then more until the readings rise to a maximum and decline again. When a leak has been located, the tester should be sure to check for laterals, as there may be an old abandoned service or some unmapped lateral. The excavation should be made at the point of highest reading, working toward the next highest point. It is well to remember that leak vibrations will carry about 100 units of distance along the pipe for every unit of distance through average soil.

Periodic Leak Surveys

The leak locator equipment can also be used to supplement regular preventive maintenance procedures by periodic leak surveys. The equipment may be mounted in a service car, with power supplied from the car battery (no polarity has to be observed). Readings may be taken and recorded about once a month on hydrants and valves according to a district map. The position of the valves and other pertinent information should be noted. The development of leaks will cause the readings to change. The leak can then be traced to a certain area and located by the methods described.

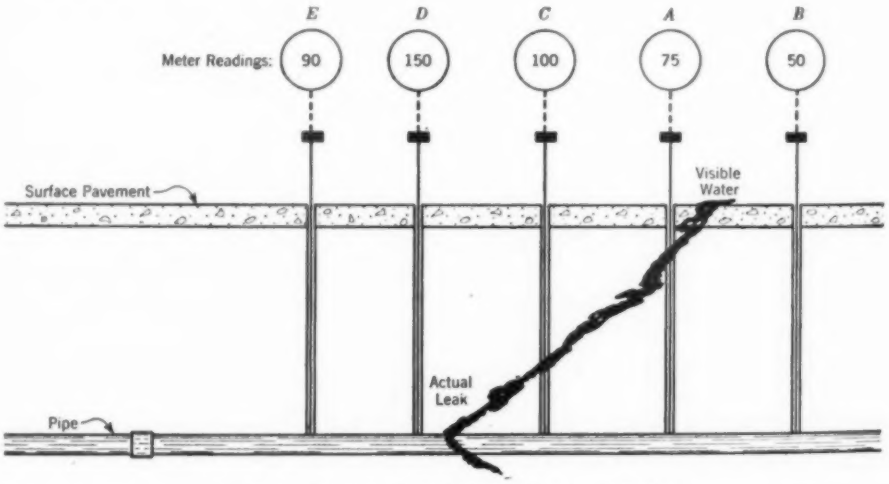


Fig. 6. Contact Sounding for Leak Location

ELIMINATING CROSS-CONNECTIONS

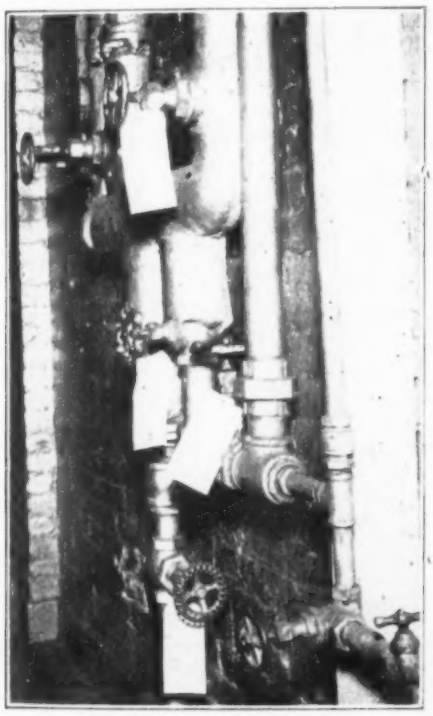
By R. F. GOUDEY

Sanitary Engr., Dept. of Water and Power, Los Angeles

THE city of Los Angeles has eliminated over 40,000 cross-connections, since the outbreak of the war, in its program to protect domestic water at harbor waterfront properties, military facilities, federal housing projects and war production plants. The project involved the installation of 10,000 vacuum breakers on plumbing fixtures, the raising of 21,000 inlets to give air-gap protection, the breaking of 2,000 direct connections to sewers, and the installation of over 2,300 backflow mechanical devices on pressure lines. The work involved over 2,000 properties, 1,200 different owners, and exceeded a cost of $2,000,000.

Historical Development of Cross-Connection Protection

From 1930 to 1938 the Department of Water and Power carried on a program to eliminate plumbing hazards and all types of cross-connections. With cooperation of the Building and Safety Department, an ordinance was passed in 1938 covering the installation of approved vacuum breakers on the discharge side of water inlets to plumbing fixtures, much as is covered by the most progressive plumbing ordinances throughout the country. The program at that time involved complete separation of potable and non-potable water piping systems and supplies. A few large fire services were permitted to have double check valves where special specifications were followed as to tight closures and material used, but their general adoption was disapproved.



1-in. City Water Line (right) Cross-Connected to 2-in. Boiler Feed Water Header on Pump Discharge (left).

Early in the program it was recognized that the policy of requiring complete separation was not only overly expensive but gave fictitious protection. It was found at photographic and plating plants where air gap protection had been obtained, that in subsequent inspections hoses had been placed on the inlets to avoid splash and to secure mixing. At waterfront properties where fresh water connection to salt water pumps and salt water piping systems had been broken, new connections had been made because it is imperative to flush combination fresh and salt water lines after every period of salt water use.

On oil well leases where tanks with rim discharge inlets and pumps had been installed to prevent backflow from oil well drilling operations and from boiler use, cross-connections were invariably made around the air-gap protection in order to secure city water pressure for fire protection. As long as property owners have what they consider as legitimate incentives to use city water under pressure, just so long will there be danger of surreptitious cross-connections being made. Based on these experiences, it is believed that *only by the proper installation of dependable mechanical devices will domestic water piping systems ever approach safety.*

Development of Mechanical Devices

The development of mechanical devices to safeguard domestic water lines has been discouragingly slow. Superior types of double check valve installations, except for some improvements in pins, bushings and clapper seat material, are fundamentally the same as they were twenty-five years ago. Double check valves have never been generally accepted as adequate protection between safe and unsafe water supplies, largely because the forces creating backflow are neither controlled nor dissipated.

An effort was made to install pressure differential relief valves which would provide openings to atmosphere under backflow conditions. An "economy" valve was developed for this purpose but did not prove satisfactory. A device with an automatic opening to atmosphere represents a most fruitful field for immediate exploitation because it destroys backflow possibilities into the water supply. Some consideration was given to a number of "switch-over" type valves to separate two supplies but which do not separate their piping systems and consequently permit polluted water to backflow after resets. It appeared, therefore, that entirely new devices would be needed and manufacturers rose to the occasion.

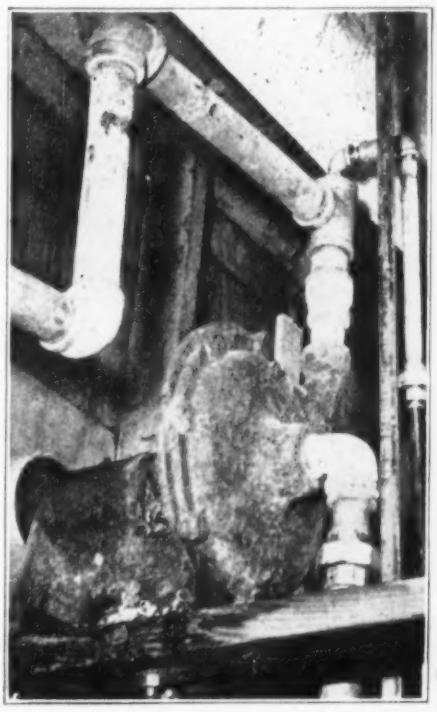
Backflow Pressure Protective Devices

The first backflow pressure protective device was a semi-manual operated Entriken valve installed at a Los Angeles swimming pool in August, 1933, followed a few months later by a second installation at another swimming pool. It provided an air-gap and back-pressure check but was not automatic. In 1938 Mr. Frank Carlton conceived of changes whereby with the addition of a vacuum breaker and the inclusion of a bellows-operated pressure differential relief valve, the device could become automatic.

With additional structural improvements this valve became the E-C Valve No. 3 for sizes ½ in. to 4 in. and was extensively used from 1939 to 1943. In 1942 an E-C Valve No. 5 was developed and one was installed which is yet the very latest in backflow protection, but is too costly for the average installation. A streamlined E-C Valve No. 6 appeared in 1944, incorporating many of the latest and best features in backflow protection and for more critical conditions has superseded the E-C Valve No. 3.

Two other companies entered the field during 1939-40. One was the Schaffer Engineering Co., which submitted the Empire valve. This device met test requirements but was too costly to commercialize. The second was the Ross Combustion Engineering Co., which produced a valve in ½-in. to 2-in. sizes for use on boiler, steam and hydraulic elevator lines. For the protection afforded, this valve still is superior from the standpoint of cost.

The Clayton Manufacturing Co. next entered the field and by 1943 was an active competitor. The company specializes in check valves and altitude control valves and combined them to make up an assembled backflow protection unit employing standard equipment. Their first unit (Clayton No. 15) included two check valves,



2-in. Salt Water Pump with 1-in. City Water Priming Line on right (no valve in picture).

a vacuum breaker and a pressure differential relief valve which operated on the same principal as the E-C Valve No. 3. A second development was a unit (Clayton No. 1) in which both checks were power operated. This device when adjusted to give positive air-gap protection under reverse flow conditions approaches the best type of protection available. Both types of valves have been widely installed during the current year.

Three national concerns have submitted devices during the past year but only one of these companies was successful in producing an approved valve. This is a Hersey No. 2 unit which includes two fire detector check valves, a vacuum breaker, and a pressure differential release valve. It locally meets the requirements of the Board of Fire Underwriters and some units have already been installed.

¾-in. By-pass Installed Around Air Gap Tank and Hidden in Grass.

As the reliability and availability of backflow prevention units gained ground, the previous rigid policy of complete separation of potable and non-potable supplies and piping systems relaxed. Experience so far has completely justified such action. A practice of "industrializing" lines at large plants was instituted. In plants having a large number of cross-connections, a point in the domestic system was selected for the installation of a backflow prevention device to isolate the majority of cross-connections The former section of the domestic system beyond the device was identified by color bands and by posting at each outlet to designate it fully as an industrial line.

All former domestic water outlets were transferred to safe ence so far has completely justified such action. A practice domestic lines and in some cases short extensions were found necessary. This practice greatly reduced the cost of over-all protection and gave the consumers the greatest use of the city supply with no incentive to make additional cross-connections.

Desirable Features in Backflow Protection Units

Some of the desirable features of satisfactory backflow protection units are:

(1) Provision for a central zone in which there is at all times less pressure than on the inlet side by providing a pressure differential release valve which opens the central zone to atmosphere with an operating head less than the initial loss-of-head past the inlet check, except when the city pressure is at or less than 2 lb. per sq. in.

(2) A drain connected to the pressure differential release valve sufficiently large to waste a reasonable amount of leakage past the outlet check without building up a head in the central zone of more than 2 lb. per sq. in. pressure when the inlet pressure is zero.

(3) No excessive spitting of water because of sudden drops on the inlet side.

(4) Control diaphragms in duplicate with a vent to atmosphere between them to avoid any danger of a cross-connection being created by diaphragm failure.

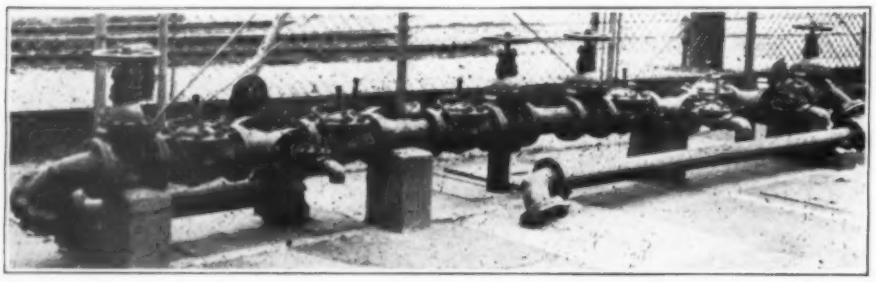
(5) Vacuum breakers included where the location of the device is at high points in the piping systems or where pumps take a suction on the inlet side of the device.

(6) Some visible positive sequence such as an alarm or water spurting to atmosphere to indicate any failure of any functioning part of the device.

(7) A location so the device will not be flooded.

(8) Adequate protection against damage from ice in freezing weather locations.

The earlier devices, including the Hankin Valve of Montreal, contain intermediate zones of higher pressure under backflow conditions than exist on the inlet side. This is objectionable because in case the inlet check leaks as much or more than the discharge check, the relief valve cannot open and backflow is unchecked. The trend, therefore, is toward the use of installations having protection zones of less pressure than on the inlet side.



Backflow Preventer (Clayton Type) on Domestic and Fire Services from Common 4-in. Inlet at Center (Vertical Line entering from Back Between Two Gate Valves). (a) Line to right contains check valve, vacuum breaker, check valve, pressure differential release and check valve. (b) Line to left same sequence but vacuum breaker is on the other side.

Cross Connection Research

The University of Southern California has established a $30,000 Foundation on Cross-Connection Research and Testing in which it is hoped that the basic principles of backflow protection can be properly evaluated; that all mechanical devices can be made correct from an engineering standpoint; and that adequate test rules can be formulated. A laboratory for this purpose is nearing completion. The Foundation is backed by many manufacturers of national standing, by local and national master plumbers' organizations, and by individuals familiar with the problem.

The war speeded up cross-connection work. Only three men were engaged in it from 1930 to 1941 inclusive, although by the end of this period cooperation had been secured with other city departments so that the net effect was the equivalent of more than three men.

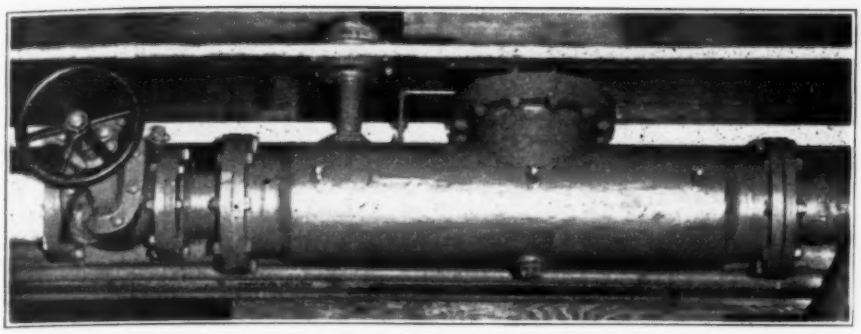
Cross-Connection Central Committee

During the spring of 1942 in order to have a more agressive program and a more uniform city policy for new construction, as well as for existing installations, a cross-connection control advisory committee was created by a joint resolution of four Los Angeles city departments covering health, water, building and safety, and mechanical engineering. The program at its peak included eighteen inspectors.

The resolution set up the author as chairman, and Mr. Roy O. Van Meter as chief inspector. The Department of Water and Power furnished office space, an office engineer and a field supervisor. The plan included assignment of twelve plumbing inspectors with rotation of others for inspection and training purposes in field work and these men were paid by the Department of Water and Power.

The Health Department at times assigned up to four men for instruction. All inspectors were cross-deputized so that police power was available regardless of the type of cross-connection discovered. Later this deputization was declared illegal, but this decision came too late to interfere with the program. The resolution required that the committee develop a unified program and so far as possible to proceed on a broad educational basis.

The merits of the cross-connection program were carefully



Industrializing 6-in. Shipyard Line with E-C No. 6 Under Wharf
(Note vacuum breaker on left. Waste valve on pressure differential is on other side. Three test cocks are on side. Inlet side is on left.)

explained to each plant owner on the basis of health and protection and added security. It has not been necessary in any case to resort to legal action. The educational program has been carried to the point where plumbers, insurance agents, boiler inspectors, hospital managers, equipment manufacturers and federal security officers have become conscious of the need of backflow protection and have actively participated in the work. The records indicate that 45 per cent of the pressure type of backflow prevention devices installed in Los Angeles were the result of this cooperation.

The committee took cognizance of the effect that cross-connections might have on the war effort and immediately intensified its program. First, a complete survey was made of the waterfront area at the harbor which included Navy, Coast Guard, Army, Air Corps, petroleum, and shipyard facilities. Secondly, a complete survey was made of all war production plants throughout the city, including all aviation plants, refineries, metal industries, colleges, housing projects, and all other plants on "master responsibility lists." Thirdly, investigations were made of all new water devices.

Early in the program there were several cases of waterfront pollution affecting military personnel because of carelessness in the use of pierhead outlets. Los Angeles has had no case of backflow for nine months, which is a remarkable record when compared with what is happening at the other ports similarly engaged in the war effort.

Elimination of Cross-Connections

Very careful consideration must be given to thoroughness in making inspections, care in office review as to requirements and remedies applicable, and presentation of recommendations to management if success is to be attained in cross-connection elimination. The following procedure was carefully exercised.

1. Before making any field inspection the following preliminary steps were taken:

(a) *A tracing of the area to be surveyed was made from a district sheet of the Water Dept., giving on a scale of 100 feet to the inch, the size of street mains, location, service numbers of the water services, and similar pertinent data.*

(b) *Information was collected from service cards giving number and size of meters, owner's name and address, and data as to meter setting with turn-on and turn-off data.*

(c) *Management was contacted to explain the historical background in connection with the purposes of the survey, the logic and reasons for cooperation in eliminating cross-connections on a uniform plan, the law backing up enforcement requirments, and an explanation of typical cross-connections and how they can be eliminated.*

(d) *Management was asked to provide proper passes to enter the premises and to appoint a water supervisor or other person to assist in the survey.*

2. In the field, inspectors prepared drawings of lines, fixtures and water equipment actually seen by them and accurately covering the following:

(a) City service connections.
(b) All city water, industrial, and process pipe lines.
(c) All plumbing fixtures as to type and size.
(d) All pumps and dual systems, regardless of function, together with pressures and practices of operation.
(e) All water using equipment.
(f) All sewers and drains.

3. Inspectors in the field made such water-use tests as to check on the accuracy of their maps and determined reasons and incentives for every cross-connection discovered.

4. Inspectors in many cases secured blueprints of water lines from management and used them only after careful verification. In many cases management requested copies of the inspector's drawings as being better than theirs so far as water piping plans were concerned.

5. Office work was carried on with equal assiduity covering such items as:

(a) A review of each cross-connection and a discussion as to the best and most economical manner to secure protection.
(b) A writing up of all cross-connections by use of standard terminology, together with remedies similarly expressed.
(c) Checking of all recommendations by office and field supervisors.
(d) Complete consideration of all legitimate city water uses which could possibly be anticipated so that there would be little danger in the future of new cross-connections being made.
(e) Issuance of recommendations in legal form setting forth instructions, laws violated, and enforcement agencies involved.

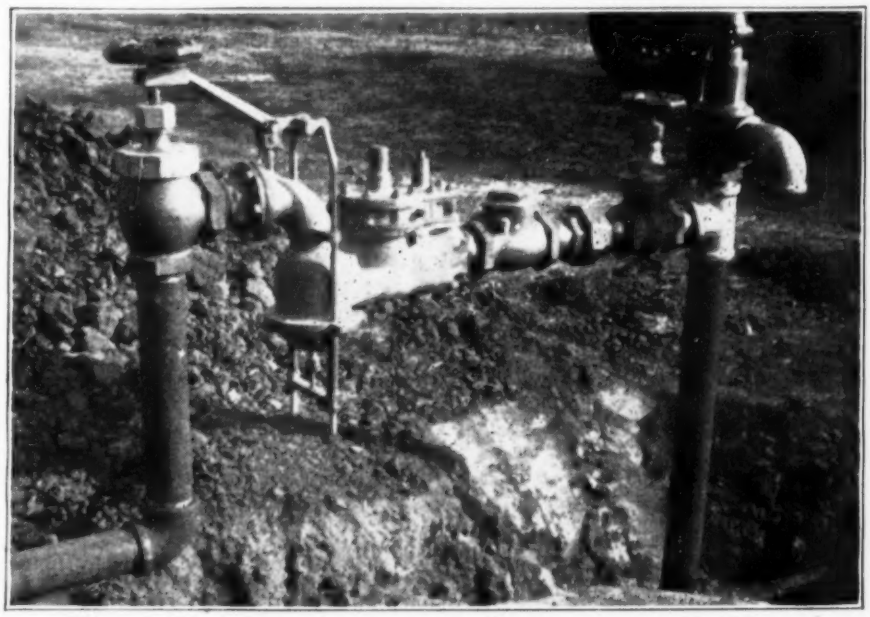
6. Proper serving of the recommendations to management is important and involves:

(a) Conferences with key personnel in which the program as a whole is again reviewed.
(b) Timing with recommendations of orders from Industrial Accident Commission, Naval and Army security officers, and interested agencies.
(c) Special efforts to explain any misunderstanding that field men at the plants may have in regard to specific recommendations.

7. Reinspections and contacts are necessary to follow up progress of the work and to lay foundation for subsequent regular inspection after completion.

8. All cross-connections must be eliminated before the file is closed.

As the program commenced in earnest the Cross-Connection Control Advisory Committee approved of a seven-point program

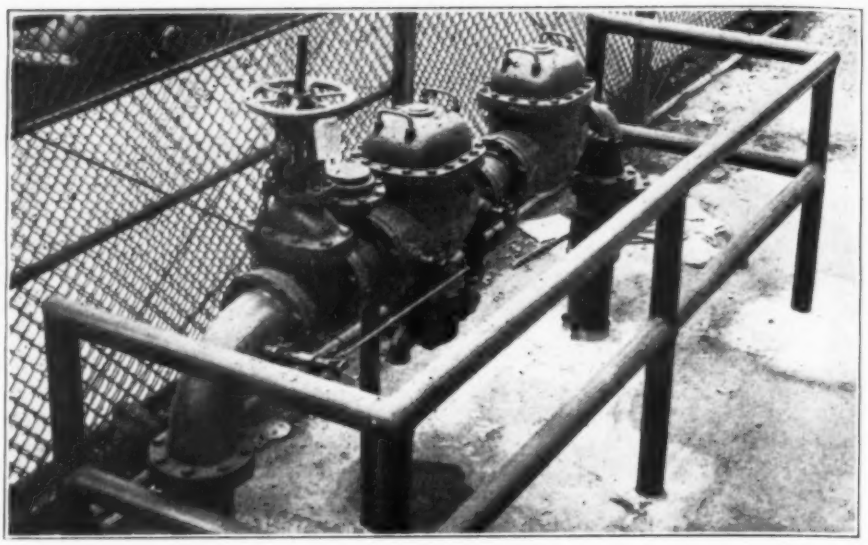


City Service (left) to Oil Lease (right) Showing 1938 E-C No. 3 Valve and Pressure Safety Valve (top right) in Addition to Relief Valve on Device.

in cross-connection control which was endorsed by Army, Navy, and public health officials at a meeting on Sept. 15, 1942, at the Naval Operating Base, Long Beach, Calif. Because this outline was carried through unchanged it is repeated here as follows:

Seven Point Program

1. Backflow protection at meter of all services to premises fronting on the harbor and to adjacent industrial and commercial plants.
2. Backflow protection at the wharf for all ship supplies.
3. Segregation of domestic and fire lines as far as possible so that no unprotected cross-connections will endanger the domestic supply from pierhead, siamese, or salt water pump intakes.
4. Elimination of all dangerous plumbing inter-connections.
5. Provision for the isolation of all pipe lines carrying processing water.
6. Adoption of color and sign scheme for designation of safe and unsafe water lines.
7. Organization of water foreman on each premises to carry out a unified plan.



6-in. Hersey No. 2 Double Check Valve Installation with Vacuum Breaker at Right of Gate, and Pressure Differential at Bottom Between the Two Checks. (Fire service approved by local Board of Fire Underwriters' representatives.)

Every conceivable type of cross-connection was discovered in this survey with such odd ones as cooling coils for X-ray tubes and direct connections to sewers through blood plasma equipment. The survey included 300 oil well properties. While the category of cross-connections was much longer than indicated in this report, the following summary is of value in pointing out the main dangers involved.

Results of this tabulation indicate that there are more direct connections to sewers through flush valves than through equipment. Accordingly, every city should wage vigorous programs in the correction of faulty plumbing. The majority of low inlets can be eliminated by mere raising, although in some cases vacuum breakers on the discharge side of valves are justified. The use of mechanical devices under pressure is largely outside the field of plumbing and involves protection against pumps for cooling, process and industrial waters as well as dual water and oil supplies. All direct connections to sewers should be physically broken.

A wide range of devices has been used to prevent backflow. The first group is vacuum breakers on the discharge side of the water inlets to plumbing fixtures or submerged gravity inlets to tanks, requirements for which are covered by American Association Standards (A40.4—1942; A40.6—1943). The second type covers pressure-operated vacuum breakers and backflow protective devices which operate on pressure systems. The following tabulation indicates the magnitude of cross-connection elimination by use of devices:

Types of Back-Siphonage and Backflow Devices

	Number
A. Plumbing type vacuum breakers	
1. Flush valves	4,000
2. Low inlets	10,000
Total	14,000
B. Pressure type backflow devices	
1. Vacuum breakers only	200
2. Backflow prevention	
Industrial lines	1,232
Dual supplies	360
Meter protection	778
Total	2,570
C. Double check valves (150 with relief valves)	200
Grand total	16,770

It is of interest to note the number of backflow prevention devices for different pipe sizes and that the most recent trend is to replace double check valves with complete devices, even for the larger sizes. The need for devices in sizes ¾-in. to 2-in. is apparent.

The cost to consumers for the entire program exceeded $2,000,000 with half of the work on the correction of plumbing fixtures, with about $500,000 involved in pressure backflow devices, and about $500,000 on pipe system changes to industrialize lines, parallel piping and breaking of sewer connections. Twenty-five contracts exceeded $25,000 and one contract reached $267,000.

Types of Backflow Protection Devices Giving Superior Protection

	E-C Valves	Clayton	Ells	Double Checks* (Hersey)	Double Checks* (Rensselaer)	Double Checks* Rebuilt	Total
½"	128	3	18	—	—	—	149
¾"	406	52	46	—	—	—	504
1"	373	56	69	—	—	—	498
1½"	57	60	12	—	—	—	129
2"	272	155	23	—	—	—	450
2½"	29	101	—	—	—	—	130
3"	74	50	—	—	—	—	124
4"	18	105	—	4	—	20	147
6"	19	34	—	29	2	50	134
8"	—	8	—	20	27	36	91
10"	—	—	—	1	1	5	7
12"	—	1	—	3	—	3	6
Total	1,376	625	168	57	30	114	2,370

*150 of these units have pressure differential relief valves.

Summary of Cross-Connections Discovered
Jan. 1, 1942—Oct. 1, 1944

	Number	Total Number
1. Plumbing—55%		
Flush valves and flush urinals	3,504	
Low inlets	6,674	
Minor hazards	12,487	
		22,755
2. Equipment—26%		
Low inlets	8,015	
Steam, boiler	2,080	
Air, compressors, elevators	257	
Washington	364	
		10,716
3. Dual supplies—9%		
Salt water pumps	83	
Wells, oil wells	330	
Industrial, process and recirculation	1,846	
Pierhead connections	1,265	
Siamese connections	94	
		3,618
4. Sewer—5%		
Direct connections	1,747	
Ejectors, water-operated	174	
		1,921
5. Miscellaneous—5% (inter-street services; lawn sprinkling)		2,237
Total		41,247

WELL CLEANING AND REHABILITATION*

By H. P. WENRICK
Associated Engineers, Palo Alto, Calif.

THE necessity for cleaning or rehabilitating a well presumes some failure of the well, resulting either in production of unsatisfactory water or in decreased yield. Water may be unsatisfactory due to: (1) its chemical characteristics, (2) contamination or (3) the inclusion of solids such as sand or clay.

Quality Improvement

In his experience with rehabilitation to improve quality, the author worked on one well which tapped several aquifers at different levels. When it began to show a decided increase in hardness and salinity, a test was made to determine which water was causing the trouble. The comparative quality of the waters from the several aquifers was ascertained, using the conductivity of the waters, as determined by surveying the well with a cell, for an index. In view of the fact that the survey showed the highest conductivity to exist at the lowest perforations in the well casing, the well was filled with cement grout to cover these perforations, and the quality was materially improved.

Similar difficulties in another well, of the gravel envelope type, were traced to the higher perforations. To seal these perforations effectively, the casing was reperforated with large holes a few feet below the point where the seal was to be placed, and the gravel was removed from the envelope to the level of the new perforations. Sand was placed inside the casing until it covered 2 ft. of the new large perforations. A 12-in. diameter liner 40 ft. long was placed inside the 16-in. casing, its weight causing it to sink into the sand about 18 in. Four sacks of cement were placed between the liner and the casing and allowed to set for a day, after which the space between the liner and casing was filled with cement grout. The sand was removed from the well and the gravel replaced in the envelope above the seal. This process reduced the hardness and salinity more than 50 per cent. Other wells with excess iron or manganese have been sealed in a similar manner.

Contamination due to entrance of surface water has been corrected in several wells by installing liners and seals or by using a jet to remove material from outside the well casing and sealing with cement grout.

The production of sand or clay from wells is due to: (1) improper development, (2) faulty perforations, (3) overpumping and (4) collapse of casing.

Improperly or incompletely developed wells are usually redeveloped. Whenever possible wells are developed or redeveloped to at least 150 per cent of the capacity of the permanent well pump. When surging at this capacity fails to produce sand or clay, the wells deliver clear water and continue to do so as long as the pumping level does not fall below the level reached at completion of development.

When redeveloping fails to produce water free from sand or clay, the perforations through which sand or clay enters the well should be located and sealed by cementing between a liner and the casing or by installing a liner slightly smaller in diameter than the casing.

In several wells upon which the author has worked, the perforations were so large opposite certain strata that the coarse sand and small gravel entered through them, and there was insufficient larger gravel to form a suitable screen outside the casing. The resulting cavity was filled with clay from above when the well was overpumped.

One well suddenly decreased in production and at the same time produced clay and sand in such quantities that the water was unusable. The pump was removed and the well sounded. About 150 ft. of the well was filled, shutting off the lower perforations. The bailer encountered an obstruction at a depth of 250 ft. An impression block showed that an inner joint of the casing had opened at the seam and folded in until the opening in the casing was less than one-third the normal opening in the 14-in. diameter casing.

A conventioned swage would probably enter the break outside the casing and force the damaged casing in, closing the opening entirely. Guides for a 6-in. swage were made to keep it on the inside of the broken casing. Before the swage was driven through, an impression block was lowered to make sure it was in proper position. This was repeated with 8-, 10- and 12-in. swages. The hard red steel well casing would spring back after the swage passed the break, so that after the 12-in. swage had been used the opening was approximately 10 in. A liner of 12-in. standard pipe was installed by welding a driving ring outside the pipe at the top and welding a cast-iron nose plug on the bottom. The cast-iron plug was made with a shoulder to fit the end of the pipe, with its outside diameter at the pipe the same as the outside diameter of the liner; below this it was reduced in diameter about the same as a swage. After the liner was driven to position, the cast-iron plug was broken out with the drilling tools and the pieces removed by a bailer. The well was then cleaned out and put back in operation.

Capacity Improvement

Wells decrease in capacity due to a lower water table or incrustation. To counteract decreased yield caused by incrustation or a deposition of material which clogs well screens, perforations or water-bearing formations, the following methods are used: (1) reperforation, (2) percussion, (3) chemical treatment and (4) surging.

Reperforation

The reperforation of the casing to provide new openings through which water can enter the well has been, in the author's experience, **the least successful** of the methods used. These failures are usually due to inaccurate logs and deterioration of the casing. About half the wells in which the casing has been reperforated have been lost entirely. The method should not be condemned because of these results, however, for with accurate well logs and good well casing, surprising results have been obtained. The capacities of several wells have been doubled by reperforating.

Use of the "Miils" knife, the "Star" perforator or even the hydraulic horizontal louver type perforator in locations where the casing had been perforated previously frequently results in tearing large holes in the casing or in the collapse of the casing.

The best results in reperforating have been obtained by using the shot perforator. The high velocity of the shot punctures the casing without the appreciable stress which results from the use of the other type of perforators. There was no evidence of damage to well casing in any well reperforated by the shot perforator.

Percussion

The shock produced by detonating either electric blasting caps (singly or in groups) or small charges of dynamite has been used to break incrustations or deposits in the perforations.

One shallow well had been drilled, cased with 16-in. 12-gage double well casing, perforated with a Mills knife, and developed to deliver 1,200 gpm. with a 20-ft. drawdown. The specific capacity of 60 was considered satisfactory for that type of well in that location.

After the well had been idle for a year, when a pump was installed to deliver 600 gpm. with a 20-ft. drawdown, it was found that the specific yield of the well had decreased from 60 to less than 4. The pump was removed and four No. 6 blasting caps detonated opposite the perforations. The pump was reinstalled, and a test showed that, with a 20-ft. drawdown, the capacity had increased from 50 to 150 gpm. To save the time and expense of removing and reinstalling the pump, guides were made to hold the caps so they would not come in contact with the casing or the pump column and shots were repeated until about 70 per cent of the original capacity was regained.

Chemical Treatment

Organic material in the perforations of the casing and in the voids of the water-bearing sands or gravel has been loosened in several wells by treating the well with a concentrated chlorine solution. The concentrated solution was placed in the wells through pipe or hose which reached to the bottom of the well. Sufficient solution was added to fill the well above the perforations. When compressed air was available, it was used to agitate the solution; in other wells dry ice was dropped into the well at 30-minute intervals. The chlorine solution was allowed to remain in the well for at least 24 hours. From 10 to 60 per cent of the lost capacity was regained in wells treated by this method when the cause of the decreased yield was clogging by organic material.

Deposits of manganese in the form of manganic salts were removed from four wells by reducing the manganic compounds to the softer, amorphous manganous compounds. This was done by treating the wells with sulfurous acid. The acid was prepared by feeding sulfur dioxide gas into a stream of water flowing through a hose into the well. This method was fairly successful. It is believed that much greater success could be obtained with this method by following the treatment immediately with swabbing or a combination of swabbing and air-lift pumping.

Calcareous deposits which had reduced well yields by as much as 70 per cent were removed by treating the wells with acid. Muriatic and nitric acids were used, but

*From the *Jour. Amer. W. W. Assn.*, April, 1947. Reprinted by permission of A.W.W.A.

not together. Either commercial inhibitors or plain bran and molasses were always used with the acid. Compressed air or dry ice was used to agitate the acid.

Surging

Forcing water through the perforations in both directions to dislodge incrustations has been accomplished by the use of bailers, swabs, swab and air lift, or dry ice.

Rapidly raising and lowering a large heavy bailer in a well opposite the perforations alternately forces water out of and then back in through the perforations. The same effect, but with a more violent action, is accomplished with a swab.

The most successful method and the one most frequently used by the author was surging the well with a swab placed on the bottom of an air-lift pump with the swab below the point at which water entered the air lift. The advantages of this system of agitation and cleaning are that: (1) a differential head can be maintained at the swab and high velocities obtained through the perforations, (2) most of the solid material entering the well is immediately removed, (3) the results of the swabbing are immediately observable when the material discharged by the air-lift pump is sampled and (4) the time of swabbing and cleaning out wells was materially decreased.

This method has been used by the author on more than 30 wells, increasing the yield of each. The application of this system was not limited to the rehabilitation of old wells, but was also used to develop new wells.

One well was drilled, cased and perforated with a hydraulic, horizontal, louver type perforator. The well was originally developed by surging with a bailer and swab and a large capacity pump. As the yield of the well was below expectations, the pump was removed and the well again swabbed, the pump reinstalled and a drawdown test made of the well. With a drawdown of 100 ft., the yield was only 300 gpm., giving a specific capacity of only 3. The air-lift swab was used to develop the well further. This additional development increased the yield to 800 gpm. with a drawdown of 60 ft., or a specific capacity of over 13.

In rehabilitating old wells, improperly developed strata were often found, and better gravel screens were developed.

If liners or other obstructions did not permit the use of the air-lift swab, dry ice was used. A plate was welded to the top of the casing, to which a 4-in. pipe coupling was welded, the plate inside the coupling being cut out. A 4-in. gate valve was then installed on the coupling. A small opening was cut in another portion of the plate, and a pressure gage attached. Dry ice sticks, 3 x 3 x 10 in. in size, were dropped into the well through the open gate valve, which was immediately closed. Pressure developed by the change of the carbon dioxide from the solid to the gaseous state forced the water out through the perforations. As soon as the pressure gage showed a drop in pressure, the gate valve was opened as rapidly as possible, and water from outside the casing rushed back through the perforations. This procedure was repeated until the pressure shown by the gage reached the same maximum recorded by the previous charge.

Conclusion

Before deciding upon a method of well rehabilitation, it is well to obtain all the information available about the well and, if possible, to determine the material or materials which may be clogging the perforations or screen. Someone with imagination and experience should be selected and given full responsibility for carrying out the program. The success of any method requiring the use of such well drilling equipment as, for example, the air-lift swab, depends as much on the skill of the person operating the equipment as on the engineering.

WATER PRESSURE

Feet of Head ⇄ Pressure

Feet Head	Pressure per sq. in.	Feet Head	Pressure per sq. in.	Feet Head	Pressure per sq. in.	Feet Head	Pressure per sq. in.	Feet Head	Pressure per sq. in.	Feet Head	Pressure per sq. in.
1	0.43	54	23.39	107	46.34	160	69.31	213	92.20	285	123.45
2	0.86	55	23.82	108	46.78	161	69.74	214	92.69	290	125.62
3	1.30	56	24.26	109	47.21	162	70.17	215	93.13	295	127.78
4	1.73	57	24.69	110	47.64	163	70.61	216	93.56	300	129.95
5	2.16	58	25.12	111	48.08	164	71.04	217	92.99	305	132.12
6	2 59	59	25.55	112	48.51	165	71.47	218	94.43	310	134.28
7	3.03	60	25.99	113	48.94	166	71.91	219	94.86	315	136.46
8	3.46	61	26.42	114	49.38	167	72.34	220	95.30	320	138.62
9	3.89	62	26.85	115	49.81	168	72.77	221	95.73	325	140.79
10	4.33	63	27.29	116	50.24	169	73.20	222	96.16	330	142.95
11	4.76	64	27.72	117	50.68	170	73.64	223	96.60	335	145.12
12	5.20	65	28.15	118	51.11	171	74.07	224	97.03	340	147.28
13	5.63	66	28.58	119	51.54	172	74.50	225	97.46	345	149.45
14	6.06	67	29.02	120	51.98	173	74.94	226	97.90	350	151.61
15	6.49	68	29.45	121	52.41	174	75.37	227	98.33	355	153.78
16	6.93	69	29.88	122	52.84	175	75.80	228	98.76	360	155.94
17	7.36	70	30.32	123	53.28	176	76.23	229	99.20	365	158.10
18	7.79	71	30.75	124	53.71	177	76.67	230	99.63	370	160.27
19	8 22	72	31.18	125	54.15	178	77.10	231	100.0	375	162.45
20	8.66	73	31.62	126	54.58	179	77.53	232	100.49	380	164.61
21	9.09	74	32.05	127	55.01	180	77.97	233	100.93	385	166.78
22	9.53	75	32.48	128	55.44	181	78.40	234	101.36	390	168.94
23	9.96	76	32.92	129	55.88	182	78.84	235	101.70	395	171.11
24	10.39	77	33.35	130	56.31	183	79.27	236	102.23	400	173.27
25	10.82	78	33.78	131	56.74	184	79.70	237	102.66	425	184.10
26	11.26	79	34.21	132	57.18	185	80.14	238	103.09	450	195.0
27	11.69	80	34.65	133	57.61	186	80.57	239	103 53	475	205.77
28	12.12	81	35.08	134	58.04	187	81.0	240	103.96	500	216.58
29	12.55	82	35.52	135	58.48	188	81.43	241	104.39	525	227.42
30	12.99	83	35.95	136	58.91	189	81.87	242	104.83	550	238.25
31	13 42	84	36.39	137	59.34	190	82.30	243	105.26	575	249.09
32	13.86	85	36.82	138	59.77	191	82.73	244	105.69	600	259.90
33	14.29	86	37.25	139	60.21	192	83.17	245	106.13	625	270.73
34	14.72	87	37.68	140	60.64	193	83.60	246	106.56	650	281.56
35	15.16	88	38.12	141	61.07	194	84.03	247	106.99	675	292.40
36	15.59	89	38.55	142	61.51	195	84 47	248	107.43	700	303.22
37	16.02	90	39.08	143	61.94	196	84.90	249	107.86	725	314.05
38	16.45	91	39.42	144	62.37	197	85 33	250	108.29	750	324.88
39	16.89	92	39.85	145	62.81	198	85.76	251	108.73	775	335.72
40	17.32	93	40.28	146	63.24	199	86.20	252	109.16	800	346.54
41	17.75	94	40.72	147	63.67	200	86.63	253	109.59	825	357.37
42	18.19	95	41.15	148	64.10	201	87 07	254	110.03	850	368.20
43	18.62	96	41.58	149	64.54	202	87.50	255	110.46	875	379.03
44	19 06	97	42.01	150	64.97	203	87.93	256	110.89	900	389.86
45	19.49	98	42.45	151	65.40	204	88.36	257	111.32	925	400.70
46	19.92	99	42.88	152	65.84	205	88.80	258	111.76	950	411.54
47	20.35	100	43.31	153	66.27	206	89.21	259	112.19	975	422.35
48	20.79	101	43.75	154	66.70	207	89.66	260	112.62	1000	433.18
49	21.22	102	44.18	155	67.14	208	90.10	261	113.06	1500	649.7
50	21.65	103	44.61	156	67.57	209	90.53	262	113.49	2000	866.3
51	22.09	104	45.05	157	68.0	210	90.96	270	116.96	3000	1299.5
52	22.52	105	45.48	158	68.43	211	91.39	275	119.12		
53	22.95	106	45.91	159	68 87	212	91.83	280	121.29		

Based on a density of 62.355 pounds per cu. ft. for water at 62°F.

THEORETICAL HORSEPOWER

$$\text{Water Horsepower} = \frac{\text{G. P. M.} \times \text{Head in Feet}}{3960}$$

Gallons per minute — HEAD IN FEET													
Ft.	10	15	20	25	30	35	40	45	50	60	75	90	100
10	03	04	05	06	08	09	10	.11	.13	.15	.19	.23	.25
15	.04	.06	.08	.09	.11	.13	.15	.17	.19	.23	.28	.34	.38
20	.05	.08	.10	.13	.15	.18	.20	.22	.25	.30	.38	.45	.50
25	.06	.10	.13	.16	.19	.22	.25	.28	.32	.38	.47	.57	.63
30	.08	.11	.15	.19	.23	.26	.30	.34	.38	.45	.57	.68	.75
35	.09	.13	.18	.22	.26	.31	.35	.40	.44	.53	.66	.80	.88
40	.10	.15	.20	.25	.30	.35	.40	.45	.50	.61	.76	.91	1.01
45	.11	.17	.23	.28	.34	.40	.45	.51	.57	.68	.85	1.02	1.14
50	.13	.19	.25	.32	.38	.44	.50	.57	.63	76	.95	1.14	1 26
60	.15	.23	.30	.38	.46	.53	.61	.68	.76	.91	1.14	1.36	1 52
75	.19	.28	.38	.47	.57	.66	.76	85	.95	1.14	1.42	1.70	1.89
90	.23	.34	.45	.57	.68	.80	.91	1.02	1.14	1.36	1.70	2.04	2.27
100	.25	.38	.50	63	.76	.88	1 01	1.14	1.26	1 51	1.89	2.27	2.52
125	.32	.47	.63	.79	.97	1.10	1.26	1.42	1.58	1.89	1 37	2.84	3.16
150	.38	.57	.76	.95	1 14	1.32	1.52	1.70	1.89	2.27	2.84	3.41	3.79
175	.44	.66	.88	1.10	1.32	1.54	1.78	1.99	2.21	2.65	3.31	3.98	4.42
200	.50	.76	1 01	1.26	1.52	1 77	2.02	2.27	2.52	3 03	3.79	4.54	5.05
250	.63	.95	1.26	1.58	1.90	2.20	2.52	2.84	3.16	3.79	4.73	5.68	6 31
300	.76	1.14	1.51	1.90	2.27	2.65	3.03	3.41	3.79	4.54	5.68	6.82	7.58
350	.88	1.33	1.77	2.21	2.65	3.09	3.54	3.98	4.42	5 30	6.62	7.95	8.84
400	1.01	1 52	2.02	2 52	3.03	3.53	4.04	4.55	5.05	6.06	7.57	9 09	10.10
500	1.26	1.90	2.52	3.16	3 78	4.42	5.05	5.69	6 31	7 58	9.47	11.36	12.63
550	1.39	2.08	2.78	3.47	4.17	4.86	5 56	6.26	6.94	8.33	10.42	12 50	13.89
600	1.52	2 28	3.03	3.79	4 55	5.30	6 06	6.82	7.58	9.09	11 36	13.64	15 15
650	1.64	2.47	3.28	4.10	4.93	5.75	6.56	7 39	8.21	9 85	12 31	14.77	16 41
700	1.77	2.66	3.54	4.42	5.30	6.19	7.07	7.96	8.84	10 60	13 26	15 91	17.68
750	1.89	2.85	3.79	4 74	5.68	6 63	7 58	8.53	9.47	11 36	14.20	17.04	18.94
800	2.02	3.04	4.04	5.05	6.06	7.07	8.08	9.10	10 10	12.12	15.15	18 18	20.20
850	2.15	3.23	4 29	5.37	6.44	7.51	8.58	9.67	10.73	12 87	16.10	19 32	21.46
900	2.27	3.42	4.54	5.68	6.82	7.95	9.09	10.24	11.36	13 63	17.04	20.45	22.73
950	2.40	3.60	4 80	6.00	7.20	8 40	9.60	10.80	11.99	14 39	17.99	21.59	23.99
1000	2.52	3.79	5.05	6 31	7.58	8.84	10 10	11.36	12.63	15 15	18.94	22.73	25 25
2000	5.05	7.57	10 10	12.63	15.15	17.67	20.20	22.72	25.25	30 30	37.87	45.45	50 50
3000	7.57	11.37	15 15	18.94	22.72	26.51	30.30	34.09	37 88	45.45	56.81	68.18	75.75
4000	10.10	15.16	20.20	25 25	30.30	35.35	40 40	45.45	50.50	60.60	75.75	90 90	101.01

NOTE:—to get the BRAKE HORSEPOWER required by the pump use the following formula:—

$$\text{Brake Horsepower} = \frac{\text{G. P. M. x Head in Feet}}{3960 \text{ x Effy. of the pump}}$$

MAINTENANCE OF WATER WELLS

By N. E. GUNDERSON
President
Layne-Northern Company, Inc., Mishawaka, Ind.

IN THE matter of water well maintenance, the principal trouble encountered is shortage of water. When such a shortage occurs, it is necessary to have all of the facts regarding a particular well in order to determine the cause. There are three principal causes for shortage of water supply. First, there is always the question as to whether the ground water level has lowered and decreased the available supply of water. Second, the condition of the well itself as it affects the capacity. Third, the condition of the pumping unit.

In order to make a proper diagnosis of the condition of a well, it is necessary to compare present operation with the operation at some time in the past, preferably original operating conditions. When a new well is constructed, the owner is entitled to three definite reports. First, a well log should be kept as the well is drilled, listing each different underground formation as it is found, noting particularly where water is encountered, a point very important in rock holes. Second, a drawing of the well should be made, giving all dimensions and length of casing, screen, and shoes. Third, a complete test should be run on the well. The latter involves a determination of the static or standing water level when the well is not pumping, then the pumping level and the gallons per minute yield for a pumping period of four to eight hours, or until the water level is stabilized.

The owner is also entitled to the same complete information on the pump installation. This should include the characteristic curve on the pump, the length and size of discharge column, the length and number of stages of pump bowl, the length and diameter of suction pipe, and the length of the air line below the base plate.

Well Tests

As soon as well trouble is experienced, a test should be run to determine current operating conditions. It is also good practice to run a test of this kind periodically thereafter, since it may be possible to predict trouble from the data at hand before it occurs. The instruments needed to run a proper test are a water meter or simple orifice plate; an air line in the well, with a suitable altitude gauge at the top; and a pressure gauge on the discharge of the pump. For the test the following should be determined: the static water level and water level after starting the pump, water level after pumping several hours, gallons per minute delivery, air line reading, and pounds pressure at the pump discharge.

The static level subtracted from the pumping level gives the drawdown or distance in feet the water level recedes when the well is delivering. Dividing the gallons per minute by the drawdown gives the yield of the well in "gallons per minute per foot of drawdown." This is the specific capacity of the well and is a very important figure.

For example, if a new well had a static water level 40 feet below the surface, delivered 200 gallons per minute, and had a pumping water level 50 feet below the surface, the specific capacity was 20 gallons per minute per foot of drawdown. If the same well at a later date showed 200 gallons per minute at a 60-foot pumping level, the specific capacity is 10 gallons per foot, or only one-half of the original yield.

Static Level

If the present static level is compared with the static level measured several years ago, or when the well was new, it can readily be determined whether the ground water level has lowered. Since there is often a minor seasonal fluctuation of ground water level, it is preferable to take periodic sets of readings throughout the year; or, as next best, to compare readings taken at the same time of each year.

If it is determined that the static water level in the ground has dropped to a considerable extent, the only practicable remedy is, of course, to locate a deeper formation, or to look for a new well field if the lowering has become serious. In an area where only reasonable demands are made upon the water bearing formations, however, this question is not likely to become serious, because the available rainfall in the area is ample to recharge the underground formation, except in cases of extreme demand.

Causes of Well Troubles

If the tests indicate that the specific yield of the well has been reduced to a considerable extent by causes other than a lowering of ground water level, the condition of the well itself should be examined to determine the true cause of the trouble. Mechanical trouble may be caused by loose material collected in the bottom. The material may come in through a hole in the casing or screen, or under the shoe of the casing. Old wells may entirely collapse due to corrosion of the casing. If it is determined that there is no mechanical trouble in the well, it is entirely possible that chemical trouble may have developed. This chemical trouble is the deposition of salts of lime and/or iron around the screen and in the water bearing formations back some considerable distance from the screen. Originally, when rain water soaks through the ground, it carries sufficient carbon dioxide to dissolve lime and iron from the soil and from the limestone formation. Thus water often becomes saturated with carbonate of lime and iron compounds which tend to precipitate from the water on reduction in pressure, which permits the carbon dioxide gas to escape. The drop in pressure which brings on the deposition is caused by the drawdown of the well which represents the drop in pressure of the ground water required to bring the water into the well. Stalactites and stalagmites in limestone caverns are of the same material as forms in a well. The deposit which forms on all types of screen material has the appearance of grey to red putty when it is brought out of the well and examined, and usually hardens upon exposure to air. The tendency of a well water to produce this deposit seems to be based more on its stability than on its hardness. In some cases, quite hard water forms no deposit; while, in others, a water of low hardness will produce a deposit very rapidly.

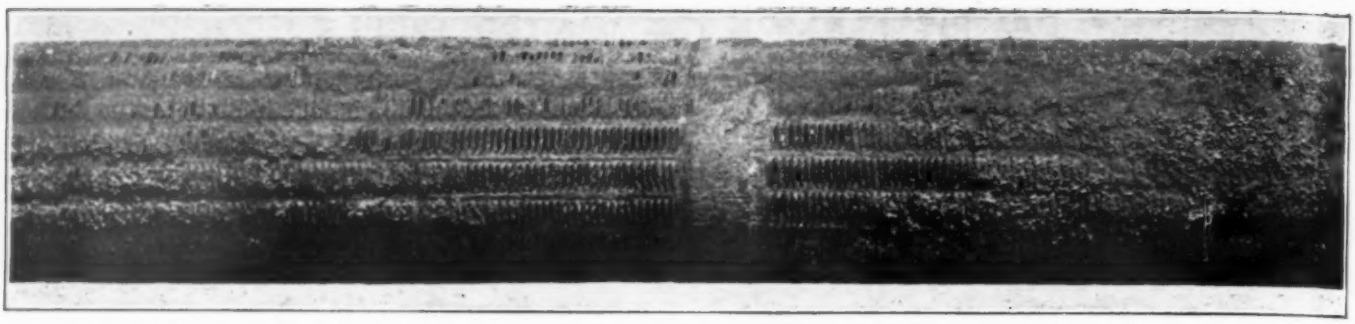
Thousand-Gallon Acid Truck
Delivering Acid Directly to Job from Bulk Station

Pump Troubles

In order to determine possible pump trouble, obtain the reading of the pump pressure gauge and convert this reading to feet. From the air line reading determine the pumping level or lift below ground. Adding the pressure in feet to the lift below ground in feet will give the total lift. Compare the gallons per minute produced at this total lift with the original pump curve and the condition of the pump can be readily determined.

If the pump is not producing the proper gallons or lift, the trouble may be caused by worn bearings or by this same chemical deposit building up in the impellers, thus choking off the flow.

If it is found that the decrease in capacity is due to worn parts, the first step is, of course, to consult the pump manufacturer. Due to the scarcity of repair materials, it is extremely



Encrusted 18-In. Screen After Eight Years' Service (A Job for Acid Treatment)

advisable to pull the pump on a regular schedule, possibly every two years, and check all bearings for wear. On an oil lubricated pump it is entirely practicable to reverse the shafting in order to expose a new bearing surface, and it is also possible, by adding a short section of shafting at the bottom, to move the shafting up to a new bearing surface. Every time the pump is pulled it is good practice to thoroughly clean and paint the discharge column in an effort to reduce corrosion on the surface. Only a good metal paint should be used which will adhere firmly to the surface.

When setting the pump in the well, as a precaution place a small rubber band around the pump bowl at top and bottom, particularly if the pump is finally set in the screen or in a casing only slightly larger than the pump. This rubber band can be cut from a section of inner tube. Any pump when running has a slight vibration, which in several cases is known to have actually cut through the screen or casing.

If the water is corrosive and the pump is pitting badly, it may be possible to reduce pitting by placing a small cylinder of zinc plate inside the horizontal discharge pipe next to the pump head, and another zinc cylinder inside the suction pipe just below the pump bowl. These should be riveted tightly inside the pipe, using iron rivets.

Mechanical Methods of Well Cleaning

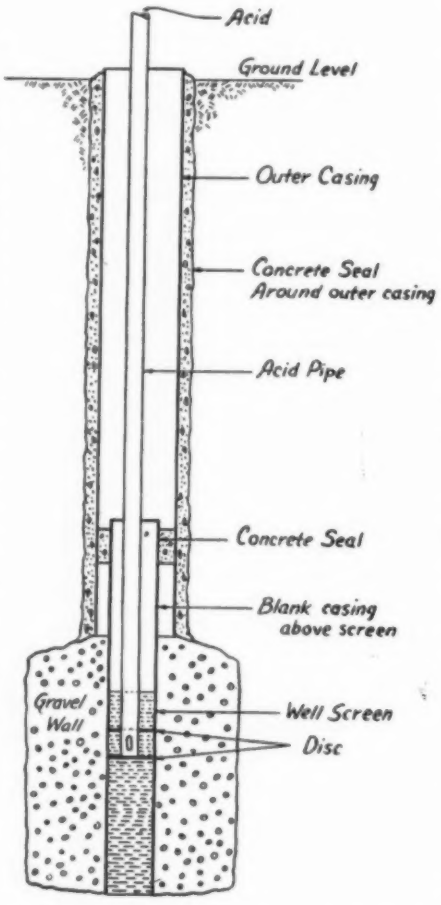
In the operation of rock wells it is quite possible for loose material to accumulate in the bottom. Such loose material may come from a hole in the casing or under the shoe. Each time the pump is removed the well depth should be carefully measured and compared with the original well depth. As explained previously, a deposit may build up in the crevices or on the wall of the rock hole. If a set of drilling tools is run in the well it is likely to brush off most of the deposit on the walls of the well. Any deposit back in the crevices can be removed only by shooting the well or by the use of acid.

If the original log indicates the depth at which the water was encountered, it is good practice to place light shots of dynamite, spaced 10 to 25 feet apart, at these old water levels with each shot ranging from 10 to 50 pounds. The principal danger in shooting is in placing the shots too close to the bottom of the casing. A peculiar fact about shooting wells is that rupture of the casing is most likely to occur at the surface of the water. If shots are not effective in restoring the well production, the next logical step is to use acid.

The acid naturally flows into the crevices from which the water was obtained and will tend to dissolve the deposit and enlarge the crevices. After placing the acid in the well, a definite quantity of water should then be run into the top of the well to force the acid back into the crevices.

Screened wells in sand or gravel are subject to the same mechanical troubles as rock wells, such as loose material in the bottom and holes in casing or screen. The most common trouble, however, is the formation of deposits around the screen and back in the formation, as described above. The two things to remember in undertaking a cleaning job are that the deposit must be loosened and then removed. If the deposit is only loosened but not promptly removed, it will tend to settle back into place with the same clogging as before. The simplest way of loosening deposits is by running an agitator or close-fitting disc up and down in the well. This device has the disadvantage, however, that when a small section of screen has been cleaned, further use of the agitator concentrates the cleaning action on the portion of the screen already cleaned. This disadvantage of the agitator can be overcome by setting a smaller string of pipe in the well with the bottom closed, and a pair of discs on the bottom of the pipe, spaced one to two feet apart, with holes in the pipe between the discs. These discs can be set at any desired point in the screen and then the agitating effect is all concentrated at a given point on the screen.

Compressed air for cleaning is often quite effective. Air should be used with the string of inner pipe as described above, and should be piped so that by simply opening and closing a valve the air is alternately blown back into the formation or the well is pumped by air lift. This method makes it possible to loosen the deposit and remove it a few minutes later.



Method of Applying Acid to Individual Screen Sections—See Text

Another method of cleaning occasionally used is to put 500 to 1,000 pounds of dry ice into the well and, if possible, cap the top of the well. The melting of the dry ice produces violent agitation and considerable pressure but does not remove the deposit. In some cases, backwashing a well from an outside supply of water has produced some improvement, but this method cannot be particularly recommended because it tends to wash the deposit back into the formation. A strong mechanical agitation can be obtained by piping steam down into the well where the rapid condensation provides a violent disturbance. All of the above mentioned methods of cleaning are what might be called mechanical methods, and there is also a mechanical method of preventing or reducing the formation of these deposits. When the pump is installed, if the suction on the pump is sealed tightly to the well screen, a strong backwash is provided each time the pump is stopped and the deposit is removed each time the pump is started. This seal also prevents exposing the water to the air at any time and reduces the tendency to deposit. A very simple seal can be made by building up a cone on the suction pipe made of strips of burlap saturated with tar. This cone should be placed so that it seats tightly in the top of the screen, just as the pump settles down on the base plate, so that the weight of the pump forces the seal into position.

Chemical Methods of Well Cleaning

In recent years the cleaning and developing of wells chemically, using inhibited hydrochloric acid, has been receiving more and more attention. In most cases, hydrochloric acid will dissolve a large percentage of the deposits. Failures are probably

due to the fact that the acid could not reach the deposit to work on it. The most important advance in acidizing is by the use of an inhibitor which largely reduces the action of the acid on all metals without reducing its action on the calcareous deposits. Inhibitors range from 80 to 98 per cent effective, but in this selection caution should be used to be sure the inhibitor is non-poisonous.

Another improvement in acidizing work is the use of a stabilizer. When the acid is first placed in a well it dissolves the "iron" and "lime" deposits rapidly, but as the acid becomes spent the power of the acid to hold the chemicals in solution is reduced, and there is a strong tendency for iron compounds to deposit again. The stabilizer prevents this redeposition and holds the iron in solution once it has been dissolved. In using acid it is highly desirable to heat the solution in the well. A hot acid solution acts much faster than a cold one and will also dissolve deposits which cannot be dissolved in cold acid.

There is a slow horizontal movement of ground water and in some cases cold acid has been actually carried away from a well before it could complete the job of cleaning. The fast action of hot acid makes it possible for the cleaning to be completed before the flow of underground water tends to carry the acid away.

It is also important in using acid to be sure that the acid reaches the deposit so that it can do its work. It is a mistake to simply dump acid into the top of the well. The acid should be placed through a hose line or pipe, the end of which is moved up through the length of the screen so that the acid is properly distributed. A still better way is to apply acid through the inner pipe device with two discs, as previously described, so that the acid can be delivered to any part of the screen desired. Systems have been worked out by which acid can be pumped under pressure through short sections of screen and then circulated, thus providing a washing action. Expanding devices have been used which permit application of heavy liquid pressure at selected points on the screen, which, added to the chemical effect of the hot acid, provides a very positive method of cleaning.

In using any method of acidizing, precaution should be taken to protect the men engaged in the work. The acid produces carbon dioxide gas, which comes out of the well and which cannot be detected. The work, therefore, should never be done in an unventilated pit because the workers might actually be "drowned" by carbon dioxide. In most cases the well top should be as open as possible with ample ventilation.

Following the cleaning operations the well should be flushed by pumping and the static level, pumping level, drawdown, output, and yield again determined and recorded.

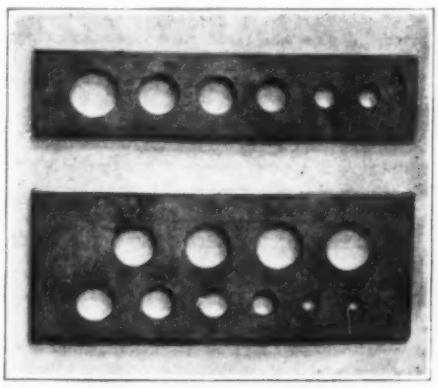
[Ed. Note: Recently some success has been had through the use of chlorine gas as a means of loosening and dissolving calcareous deposits in wells. The gas pressure serves to surge the water and the chlorine attacks the carbonate, producing carbon dioxide, hypochlorous acid and the soluble chlorides without first forming any hydrochloric acid. Hypochlorous acid is a very weak acid but will further attack the calcareous deposits.]

A GAUGE FOR METER CHANGE GEARS

By DON. C. CALDERWOOD
Engineer, Pennichuck Water Works
Nashua, N. H.

YOU may find the following gadget useful in your meter repair shop. This probably will be especially true if due to war conditions you have had to replace at least a part of your trained meter repair crew with men of less experience and ability.

Of necessity most meter repair shops carry a good stock of register and spindle change gears and regardless of make most of these gears look very much alike. Most water departments also use several different makes of meters and no matter how hard you try to keep these gears separated and in the right place they get mixed up as to size, make, and number of teeth. A trained man with a micrometer and the manufacturer's specifications can separate and properly sort out these gears, but it is a time consuming job.



Meter Change Gear Gauge

In order to facilitate this sorting, to keep our stock in order, and to assist in the meter repair work we had a set of gauges made, each gauge applying to one make of meter. A gauge consists of a piece of brass plate (nearly any metal will do) with holes drilled to the exact diameter of the change gears used in that make of meter. For example, we have several hundred "Watch Dog" meters which use change gears of the following diameters.

TABLE I
"WATCH DOG" CHANGE GEARS

Meter size	Gear Diameters—Register	Gear Diameters—Spindle
⅝"	.847"	.490"
¾"	.805"	.705"
1" & 1¼"	.522"	1.000"
1½"	1.000"	.522"
2"	.805"	.705"

Accordingly we had a gauge made with the holes of the above six diameters bored through the metal and properly stamped with the name of the meter and the diameter of each hole—see cut.

Some meters, such as the Hersey, use a slightly different system. Hersey change gears of more recent manufacture are stamped with a letter that indicates the outside diameter, but some of the older gears are not stamped or the markings are obliterated so the following table was made.

TABLE II
HERSEY CHANGE GEARS

Meter size	Model	Gear Diameters—Spindle		Gear Diameters—Register	
⅝"	F	B	.312"	X	1.008"
⅝"	D, HD, FF, HF	E	.394"	V	.937"
¾"	F	K	.541"	W	.979"
¾"	D, HD, FF, HF	P	.703"	S	.815"
1"	F, D	S	.815"	P	.703"
1"	FF, HF, HD	U	.875"	N	.645"
1¼"	D	U	.875"	N	.645"
1½"	F, D, HD	E	.394"	Z	1.125"
2"	D, HD	K	.541"	W	.979"

In this case we took another piece of metal and bored eleven holes to exact size and stamped not only the diameter of the hole but also the letter indicating the diameter.

These are merely two examples of how this problem can be handled. It goes without saying that you should limit your gauges and diameter of the holes so that they apply only to the make, size and model of the meters you are using. The information and data concerning the diameter of the change gears is probably in your files but should the information be lacking, the manufacturer will gladly supply you with it.

In making up your tables of diameter combinations for the various sizes and makes of meters you can carry it to any degree of refinement you wish. Originally our tables consisted only of the diameters of the gears and the combinations as listed in this article but more recently we have revised it to include the usual number of teeth on each gear to obtain the correct registration and the various number of teeth obtainable in a gear of any given diameter.

Like many new things the older employees rather laughed at the need of such a set of gauges, but now they freely admit that it speeds up the repair work and is a vast improvement over the old system.

In regards to the gauges themselves they are not hard to make, but we were fortunate in that they were obtained at no cost to us. There is a local school training men for jobs in defense plants and the instructor of machine shop was glad to have one of his pupils do this work as part of his training. The purpose of this article is only to give you the general idea so that you can change and adapt it to fit your own needs.

RECOVERING WELL CAPACITY WITH CHLORINE

By W. E. HUSTON

Water Station Foreman, Physical Plant Dept., Univ. of Ill., Urbana, Ill.

IN 1935, two gravel-packed screen wells were constructed for the University of Illinois by a drilling contractor at a cost of about $25,000. At first successful, the flow from the wells, which were known as No. 10 and No. 11, declined rapidly. In March 1940, Well No. 10 was delivering approximately 25 per cent, and Well No. 11 approximately 45 per cent of the original specific capacity.

Diminishing well capacity is not uncommon in this region, but output from these wells had fallen off so greatly that the university supply was threatened. In 1940, as described by White[1], Well No. 10 was treated with acid. Since both calcium and magnesium bicarbonate were found in the well water, it was believed that calcium carbonate deposits might be encrusting the screen. An unsatisfactory increase in capacity, from 24.5 to 38 gpm., made this explanation seem inadequate, however, and it was decided to treat with chlorine as well.

Chlorine treatment raised the capacity from 38 to 50 gpm. per foot of drawdown. This was considered satisfactory even though the increase was somewhat less than that reported by Brown at Eau Claire Wis.[2] The result seemed to indicate obstruction by an organic growth rather than calcium carbonate, and so the chlorine treatment was used before the acid in Well No. 11.

In Well No. 10, 52 per cent of the gain in specific capacity had been obtained by use of the acid; in Well No. 11, which received the chlorine before the acid treatment, 80 per cent of the gain in capacity was obtained by the chlorine. Figures 1 and 2 portray briefly the original and subsequent treatments and their results.

In 1941, the decline in flow from Well No. 10 was again critical, while flow from Well No. 11 had receded but slightly. The decline in both wells was serious in 1942, but no treatment was undertaken because of a wartime shortage in the chlorine supply.

In 1943, the pumps in both wells were breaking suction. Treatment with chlorine produced better results in Well No. 11 than in Well No. 10. This may have been due to differences in the construction of the wells. The 55 ft. of shutter screen in Well No. 10 is never totally submerged, while the 25 ft. of screen in Well No. 11 is submerged when the pump is idle. In the author's opinion, the results obtained in 1943 reflect the difference in the treatment of the wells in 1940, when acid was applied prior to chlorine in Well No. 10 and chlorine prior to acid in Well No. 11.

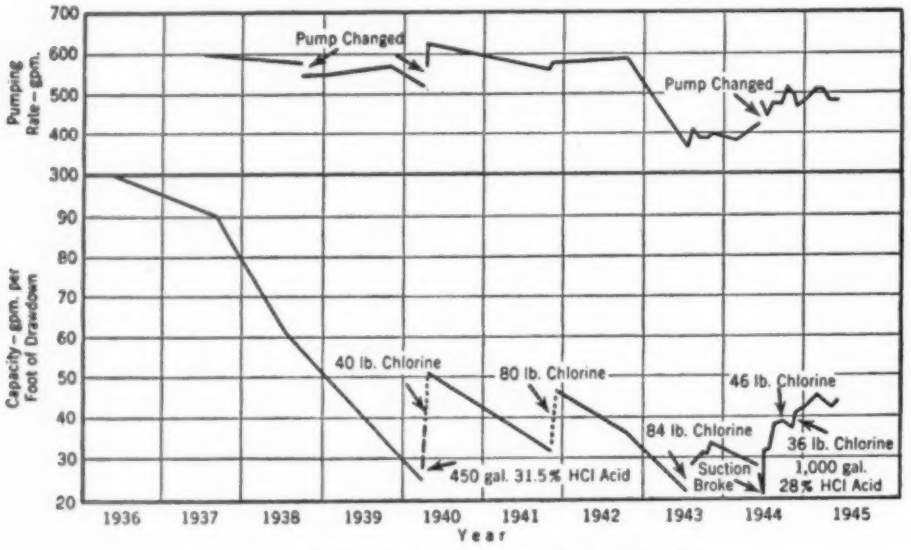


Fig. 1. Recovery of Capacity of Well No. 10

Chlorine and acid were applied in both wells in 1944, and experience seems to indicate that it is possible to overtreat with both. On starting the pump at Well No. 11, after applying acid with the pump in place, no water at all was obtained, but, after starting and stopping the pump at short intervals for several hours, the condition improved. Two months later, the flow from the well was greater than it had been before the acid was applied.

A study of Figs. 1 and 2 indicates that the specific capacity of a well is not a straight-line function, but varies with the rate of pumping.

Some of the minor fluctuations shown may have been caused by variations in ground water levels or interference from other wells at the time the measurements were made.

References

1. White, H. L. Rejuvenating Wells With Chlorine. *Civ. Eng.*, 12:263 (1942).

2. Brown, E. D. Restoring Well Capacity With Chlorine. *Jour. A.W.W.A.*, 34:698 (1942).

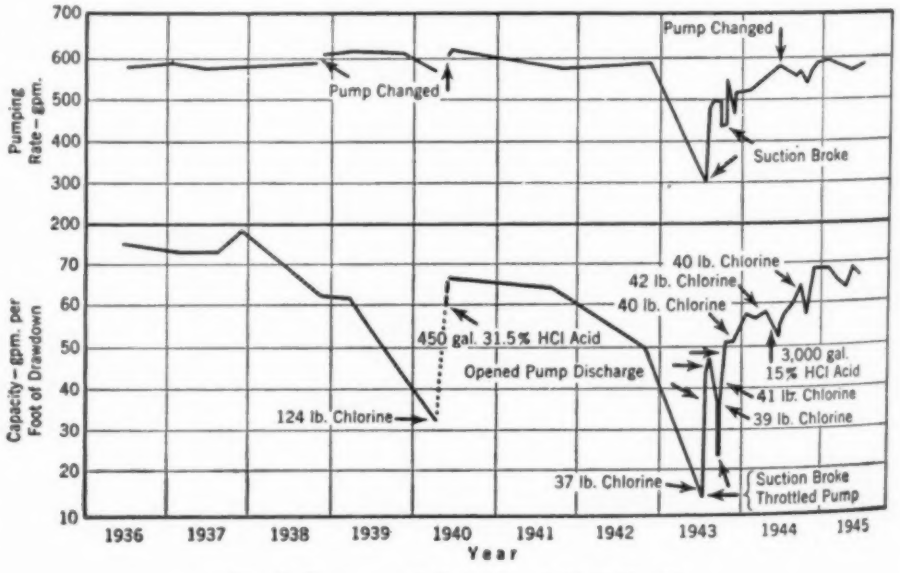


Fig. 2. Recovery of Capacity of Well No. 11

PURCHASE AND MAINTENANCE OF DEEP-WELL PUMPS*

By L. J. ALEXANDER

Design Engr., Southern California Water Co., Los Angeles, Calif.

THE Southern California Water Co. has 107 turbine pumps in operation and purchases an average of 10 complete units each year. These pumps are located in 29 operating districts. Geographically, the districts are scatttered from the vicinity of Sacramento to the Imperial Valley. They operate under climatic conditions ranging from the hot, dry desert to the snow-clad San Bernardino mountains. The wells in which the pumps operate are located at elevations varying from sea level to more than 7,000 ft.; the motors driving them vary in size from 7½ to 150 hp., and the capacity range is from about 100 to more than 2,200 gpm. In direct lift of water from the well, the variation is from just a few feet to more than 500 ft. below the surface.

The wide range of pumping conditions provides opportunities to shift pumps from one location to another, thereby practically eliminating the factor of obsolescence. A pump can always be installed in a well or system where it will operate to best advantage. With specifications standardized, it is possible to make these transfers even though there is considerable variation in character and quality of the water being pumped.

Wells and Water Quality

Wells drilled in Southern California are of two types: the California cable tool and the rotary gravel envelope. The cable tool method was developed in the early days of well drilling in Southern California because of the character of the geological formations into which wells must be drilled. These are all unconsolidated formations of the Recent, Pleistocene and Pliocene geologic epochs. The unconsolidation is such that open-hole drilling is impossible; the well casing must follow the drill. After the well is drilled, the casing, which is then in place, is perforated opposite water-bearing formations.

Rotary gravel envelope wells have preperforated casings set in the drilled and well-mudded hole. Gravel is then placed between the casing and the wall of the drilled hole.

The Southern California Water Co. has wells of both types, with depths ranging from less than 200 ft. to more than 1,900 ft. The unconsolidated formations in which these wells are drilled are so unstable that, regardless of the type of well, it is often impossible to keep out fine sand or silt. Even after very careful development of the well, it is occasionally necessary to resort to the use of a column check valve in the construction of a pump. In doing this a column check valve is installed immediately above the pump bowls to prevent water from draining out of the pump, with a consequent reversal of the flow from the well into the formation.

Sand within the water passages of the pump literally blasts away metal of bowls, impellers, shaft, casing and tubing. Experience has shown that bronze withstands this sand cutting better than any other metal. Porcelain-enameled cast-iron impellers have been tried, as porcelain is harder than sand and, thus, might be expected to withstand the abraison; but sand cuts into the cast iron where the enamel has been machined off, and cavities develop between the porcelain and iron. It is only a matter of time until the porcelain spalls, due to corrosion of the iron.

Because many of these formations from which water is extracted were laid down under water, there are large areas where gases such as methane, carbon dioxide or hydrogen sulfide are entrained. These gases (or air from water falling from perforations above pumping water level) cause turbulence in the pump, and, in turn, excessive corrosion. Bronze and stainless steel withstand such corrosion better than iron or steel. In the pump column, at the top of the bowls, a short section of bronze tube will often withstand the corrosion caused by turbulence.

stainless steel shaft, bronze bowls and impellers in the bowl assembly, a 5-ft. section of bronze oil tube, a stainless steel line shaft from bowls to static water level, with a coating of coal-tar enamel outside the oil tube and inside and outside the eduction pipe.

To check corrosive waters, the Wintroath Pump Co. has demonstrated that the better the grade of metal, the more resistant it is to corrosion. Many pump manufacturers, for their standard sales product, use an ordinary run of foundry gray iron. The Wintroath analysis shows a rather high electric potential between ordinary gray iron, bronze and stainless steel, which seems to be additional proof of what practice has long demonstrated: that the

TABLE I
Analysis of Water

	City Creek	Foothill	Garvey	Wadsworth	Golden West	Avalon	Colden	Pacific
Sodium	104.4	37.7	19.6	378.6	32.2	49.5	57.3	63.7
Calcium	1.2	32.1	37.6	10.0	57.5	69.6	106.8	105.2
Magnesium	Trace	6.7	11.2	2.5	10.3	13.4	21.8	42.7
Sulfate (SO_4)	84.5	7.2	18.2	3.8	44.1	91.2	197.3	179.0
Chlorine	19.0	12.0	20.0	198.0	29.1	33.0	53.5	82.0
HCO_3	109.3	201.3	164.7	699.0	207.3	231.7	244.0	335.5
Total solids	319.0	321.8	284.5	1319.9	392.9	492.4	698.4	839.1
Carbonate hardness	3.0	107.5	135.0	35.0	170.0	195.0	200.0	275.0
Other hardness	....	....	5.0	....	16.5	34.0	156.5	162.0
Total hardness	3.0	107.5	140.0	35.0	186.5	229.0	356.5	437.0

The well waters pumped represent a wide range in chemical characteristics. Hardness varies from just a few to more than 500 ppm.; the pH is between about 7.3 and 8.0. Total solids vary from less than 100 ppm. to a maximum of 1,500 ppm. In several wells, free carbon dioxide appears and, in a large number, free hydrogen sulfide. Some waters have no trace of either iron or manganese; others have as high as 2 ppm. iron and 1 ppm. manganese. Table 1 shows this wide range of chemical character in the water produced. It has not been possible to relate corrosion rates directly to the acid radicals contained in natural waters.

The most troublesome conditions under which pumps operate exist in those wells in which the waters have been highly contaminated with the iron and sulfur group of slime-forming organisms, and contain as much as 2 ppm. iron and 1 ppm. manganese and have a high concentration of free hydrogen sulfide. Such waters are devoid of dissolved oxygen, but the slime-forming organisms are anaerobic. Slime coatings of considerable thickness will form even on highly polished rotating parts, such as the impellers. As the slime increases in thickness, the water passage space is reduced in area; and the efficiency of the unit reduced. Occasionally graphitic corrosion takes place to an alarming degree where these slime-forming organisms are present. Bronze parts are the least affected by the slime formers.

Corrosion

Corrosion of turbine pumps results from several causes: chemically corrosive waters, entrained gases, bacteria and differences in electric potential between parts of the unit. How each factor operates or affects the other is not known, but it is obvious that corrosion does occur and that preventive measures are necessary.

In extreme corrosion, whatever the cause, the best preventive measures are to use a finer the metallurgy, the better the completed product.

Speed of rotation is another factor. It seems that the higher the speed, the greater the rate of corrosion. The author has found no satisfactory explanation of this correlation, and cannot determine whether it is due to corrosion alone, or partly to the turbulence caused by high velocity.

No attempt has been made to weigh individual parts of the pump to determine the extent of corrosion or wear in terms of the percentage of metal lost. Such an analysis in turbine pumps has little practical value because corrosion and wear never take place uniformly. A section of pump casing may lose less than 1 per cent by weight and still be unsafe because the casing is pitted. If pitting is allowed to continue, holes will cut through the casing and, under the high head of water in the pump column, act as nozzles. Wells have been damaged by such holes drilled through the well casing, and the loss of water through holes causes appreciable loss in pump efficiency. Corrosion and pitting at or near threads of the casing so weakens the pipe that failure can occur at a joint. When this occurs, the entire weight load of the pump and the hydrostatic thrust of water load are transmitted to the motor bearing and the rotating impellers. Such loads will wreck the entire unit.

In the pump bowls, a fraction of one per cent loss in weight, if in certain places, may be serious. On the other hand, if corrosion or sand cutting is uniform throughout, a 15 or 20 per cent loss in weight may not be serious.

Corrosion of the tubing may permit water under high head to enter the peripheral space between the tubing and the rotating pump shaft. Water will then shortly find its way out through the top of the tubing. When this occurs, the motor windings are often sprayed with water, resulting in a burned-out motor. Of less serious conse-

*From the *Jour. Amer. W. W. Assn.*, Oct., 1946. Reprinted by permission of the A.W.W.A.

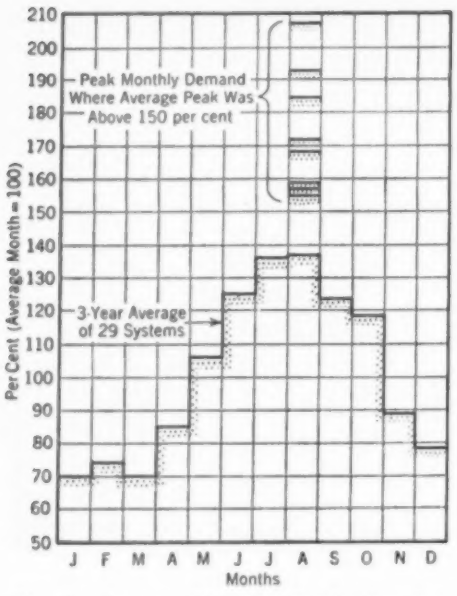

Peak Monthly Demand Where Average Peak Was Above 150 per cent
3-Year Average of 29 Systems
Per Cent (Average Month = 100)
Months
J F M A M J J A S O N D

Fig. 1. Average Monthly Production for All Systems

quence, but equally troublesome, is the resulting corrosion of the line shafting. The company's specifications do not permit a packing gland at the top of the tubing, because a packing gland prevents the appearance of oil and water at the pump head. When even a very small hole appears in the tubing it can be detected quickly and immediately repaired.

Very slight wear in the motor bearings, even a fraction of one per cent, may change the position of the impellers in the bowls, and cause them to wear excessively. The efficiency of the unit is lowered almost immediately, even before serious wear occurs. Excessive wear in motor bearings also causes misalignment of bearing housings. Oil is thrown out of the housing and, in a very short time, saturates the motor windings so thoroughly that nothing short of rewinding the motor will save it.

No mathematical relationship or formula can be developed or deduced to replace experience and visual inspection in the choice and extent of repairs and replacements to parts of the pump, when it is pulled for overhaul.

Variation in Demand

The variation of consumer demand in arid countries is great. All living things require water regularly, but in Southern California nature provides water only in the winter rainy season. Irrigation is therefore necessary. Domestic water service must provide for irrigation of lawns, shrubs and flower gardens, as well as for industrial and household consumption.

Fig. 1 shows the Southern California Water Co. monthly production compared to the average month (taken as 100 per cent). Together with the 3-year average for the 29 systems, the maximum months for several of the smaller systems are also shown. It appears that the smaller the system, the greater the peak demand. The average day of the maximum month averages nearly 140 per cent of the yearly average day; but the average day varies widely in the various systems. The average daily demand for 1945 is shown in Table II. This table also shows the relationship of the maximum day to the average day.

There is an even greater variation in hourly demand. Fig. 2 shows the average variation for each hour of the maximum day. The broken line represents the average of three consecutive maximum days in the Lennox system in 1942.

These curves all show the necessity for a large available capacity in primary pumping equipment. On the other hand, they show that, for large portions of the year, much of the equipment must remain idle. Experience has demonstrated that idle equipment deteriorates nearly as rapidly as operating equipment. The causes may be different, but replacements are just as costly. To overcome this problem partially, all equipment is operated at least once a week.

Weekly operation keeps the well in good order, dries out the motor windings, prevents "freezing" of bearings—particularly in the line shaft—tends to reduce the accumulation of slime growths and assures the operators that the equipment is in good order. This last is important because all equipment must "cut in" quickly and automatically in case of fire.

Planned Operation

Although all equipment is automatic, the time each unit operates can be predetermined. The general plan of operation to assure an adequate dependable primary supply is laid out in the engineering department. This plan is based on a study of the distribution pipe system and the location of the various pumping plants. Elevated storage is always considered as a balance against the maximum hour, and it is also desirable to consider it as a safety factor. Each plant is automatic, operation being controlled by pressures within the adjacent distribution system. Other factors entering into the setting of these controlling pressure ranges are: the quality of water produced at the plant, the efficiency of equipment, variations in demand, the needs of fire protection and the manpower available to operate the equipment.

The carrying out of these planned operations is under the direction of the construction engineer, who has charge of all field work on new construction, as well as maintenance, repair, replacement and operation. The district superintendents, of course, are "on the ground" and carry out most of the details of the operation of pumping plants.

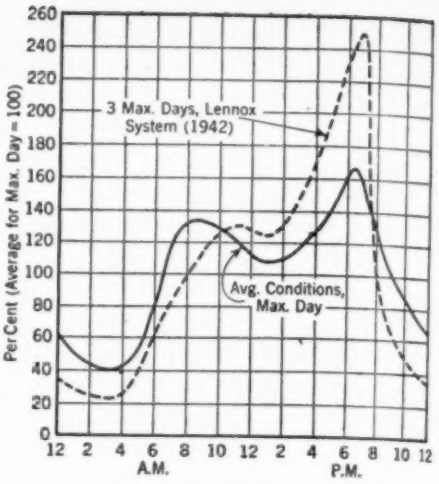


Fig. 2. Average Demand on a Maximum Day

Checks on Operation

To check the overall engineering plan, periodic pressure surveys are made. Complaints of poor water service are also checked against planned operation. The operation policy is to render an adequate and dependable water supply to all consumers at all times. During the war years, this has at times been difficult, but, with a little more time and the delivery of some needed materials, the policy will again be maintained.

All the factors involved in such operation make necessary continuous checks on equipment. In doing this, three principal checks are made regularly on all operating equipment.

The first check is made in the statistical branch of the engineering department. All field pumping records are assembled and checked in the office and the performance of each pumping plant is checked each month. A computation is made of the power in kilowatt hours consumed in pumping 100 cu. ft. of water (the company's unit of water measurement). This figure is balanced against the pumping water level in

TABLE II
System Demands

System	County	No. of Customers* 3/13/46	Gals. per Customer* 1945	Max. Day, Per Cent of Avg. Day, 1945
Artesia	Los Angeles	547	423	199
Barstow†	San Bernardino	876	822	181
Bear Valley	San Bernardino	655	202	386
Bloomington	San Bernardino	376	394	193
Calipatria‡	Imperial	290	1621	...
Niland	Imperial	125	...	...
Bell	Los Angeles	2,549	460	174
Florence-Graham	Los Angeles	5,986	695	135
Cardena	Los Angeles	4,048	432	230
Lawndale	Los Angeles	2,747	378	201
Lennox	Los Angeles	4,569	370	172
Normandie	Los Angeles	1,650	324	198
So. Los Angeles	Los Angeles	7,905	259	208
Claremont	Los Angeles	1,185	707	311
Cypress	Orange	126	386	243
Highland	San Bernardino	603	388	188
Hollyda e	Los Angeles	1,451	404	203
Huntington Beach	Orange	1,549	694	267
Oak Park	Sacramento	1,104	497	293
Ojai	Ventura	591	478	166
Olive	Orange	176	335	278
Placentia§	Orange	623	311	...
Atwood	Orange	...	...	...
Sunland-Tujunga	Los Angeles	3,359	432	201
Venice-Culver City	Los Angeles	14,978	515	139
Walnut Grove‖	Los Angeles	62	...	...
Wilmar	Los Angeles	3,062	325	190
Los Alamitos	Orange	215	527	172
Stanton	Orange	209	229	228

*An average of 4 consumers is served by each customer's service connection.
†Industrial use eliminated.
‡Unmetered supply; consumption determined from several tests.
§Part of supply unmetered.
‖New system averages not established.

the well to determine the power, in kilowatt hours, required to raise 100 cu. ft. of water 100 ft.

The second check is the reading of power and water meters by the field operator on his daily rounds.

The third check immediately follows any variation in the consumption of power per 100 cu. ft. of water produced. This is the field check by engineers of the construction department of the efficiency of all the pumping units at the plant.

Wear or corrosion is immediately evident from one or all of these checks. During the war, when materials were difficult to obtain these checks became very important; they were the insurance against failure of the primary supply of water. The importance of this insurance lies in the fact that the total number of customers served during the last five years has increased nearly 10 per cent, whereas the available capacity of turbine pump production has decreased slightly. The result is that on maximum days every piece of equipment is in operation to meet the maximum hour.

Maintenance Program

Both the construction department and the engineering department work in close co-ordination on all phases of the company's operations. Seventeen years of co-operation has built up mutual understanding of the problems of each department. The result has been the adoption of certain theories and policies regarding design, maintenance and repair and operation.

The turbine pump maintenance program attempts to keep equipment in the best operating condition possible. Experience has shown that this policy can be carried out by pulling pumps for overhaul every 2, 3, 4 or 5 years.

Two-year schedule. Where the pumps are operating in "bad water," containing iron and sulfur organisms, or iron and manganese accompanied by hydrogen sulfide, or in wells which produce large quantities of sand, with the pumps operating under heavy-duty conditions—that is, for long hours every day in the year—a 2-year overhaul interval is scheduled.

Three-year schedule. No pump in "bad water" is permitted to operate beyond a 3-year period regardless of the number of hours which it may have operated.. Normally, heavy-duty units are overhauled on a 3-year period, even in good quality waters.

Four-year schedule. Pumps operating under relatively light duty and under "fair" water quality conditions are overhauled every 4 years.

Five-year schedule. Regardless of the characteristics of the water or the conditions of pump operation, no pump is permitted to run more than 5 years without an overhaul.

Extent of Repair and Replacement

When pumps are pulled from the well they are completely disassembled in the field or in the pump company's shop. Each part is subject to inspection by a trained engineer.

Generally, the inspections reveal the need for the following repairs:

Bowls

The top and bottom bearings or bushings are replaced. The replacement of main bearing housings or castings, however, is seldom needed. New wear and seal rings

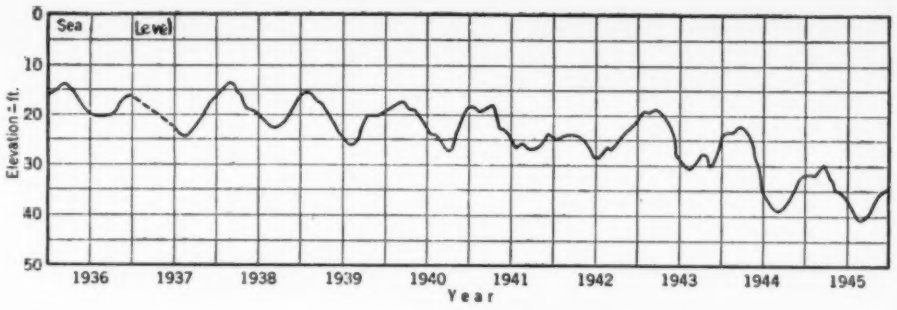


Fig. 3. Variations in Static Water Level of a Well

are nearly always installed, on both intermediate bowl castings and impellers. Intermediate bowl castings are replaced when not sufficient metal remains to permit machining for the installation of new rings or when excessive corrosion or sand cutting is apparent; and impellers are replaced for the same reasons. A new stainless steel pump shaft is installed only if injured in disassembly or when there is a change in basic bowl design.

Column

The most serious pump column replacement problem occurs with that portion of

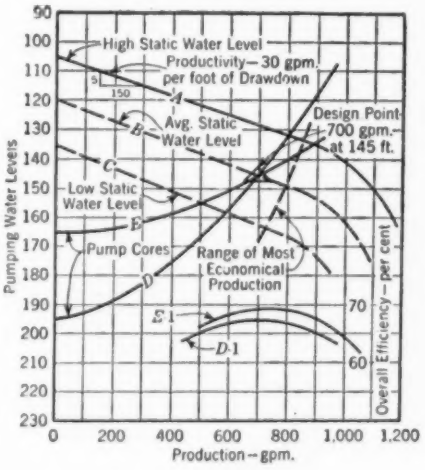


Fig. 4. Design Conditions for a Well

the column immediately above the pump bowls. This section is subject to more corrosion, sand cutting and wear of all sorts than any other, probably as a result of some turbulence in the water as it leaves the bowls. The first joint of casing above the bowls generally needs replacing or "pup jointing," that is the replacement of a portion of the casing with new pipe. Pup jointing is accomplished by cutting off the corroded section and using a pipe coupling to install a short piece of pipe that makes up the required length. The oil tubing often shows results of corrosion both inside and outside, between the static and pumping water levels. This occurs because water alternately will rise within the oil tube to the static water level of the well and drain out to the pumping water level during operation. The line shaft also becomes corroded within this range and must be turned end for end and reground at the bearing points on each overhaul. Often individual pieces of shaft can be shifted within the assembly to overcome wear or corrosion. The line shaft bearings or tubing couplings are all sized, and are replaced if they show wear of 0.012 in.

Motors

For each overhaul, motors are taken to the company's electric shop, where they are cleaned, reinsulated, and have their bearings checked, so that the motor goes back as nearly as possible in perfect condition.

Manufacturers' Service

Even under emergency conditions, working around the clock, it requires two or three days to pull, tear down, inspect, repair and reinstall a deep-well turbine pump. Failures of pumping equipment occurring on peak days or even peak months can be serious. It is the general practice in designing water supplies utilizing ground-water reservoirs to have primary capacity to meet at least the maximum day. Maximum hours can be taken care of by elevated storage.

During the war, it was nearly impossible to obtain sufficient materials to keep production facilities ahead of demand. It seems even more difficult now. The rate of population growth in Southern California is greater than ever before. It is, therefore, highly important to keep equipment in the best possible condition.

Emergencies, however, do occur. It is then necessary to move, and to move quickly. The company has always required that repairs be made by the manufacturer. Consequently, deep-well pumping equipment is purchased only from those manufacturers who are prepared to render immediate service. Only three manufacturers who can meet this specification have yet been found.

Choice of Pump

As is true in any arid country, Southern California has cycles of rainfall. These cycles recur from season to season and from year to year. The result is that the underground storage, as reflected in static water levels, varies both seasonally and by cycles of years. The season-to-season cycle indicates a range—often as much as 50 ft. —from a high in February and March to a low in September and October. The general conditions are illustrated in Fig. 3, which shows the variation in static water levels for a 10-year period on one company well.

Various water-bearing formations, whether Recent, Pleistocene or Pliocene, show different productivities. This productivity can be rated as the production volume in gallons per minute per foot of drawdown, and is the slope of Curve A, Fig. 4. The most economical production is always on the straight line portion of the curve, a short distance before the accelerated downward slope begins. No pump is ever chosen with a capacity greater than the most economical production of the well, as this factor seldom coincides with the

maximum efficiency of the pump. Figure 4 shows the design conditions of a recent well. The well was completed in the high static water level period and drawdown Curve A was obtained from test. Curves B, the average static water level and C, the low static water level, have been estimated from experience. Curves D and E are those submitted by two manufacturers for head capacity performance of a turbine. Curves D-1 and E-1 are the efficiency curves (ratio of power input at the meter to theoretical power required) and include all losses incurred in the motor, line shaft and bowls, and within the pump by water friction. Both performance curves were submitted by pump manufacturers to meet the design point.

It is interesting to note that turbine pumps are sold and purchased to meet one design point. This practice, promoted by the California Pump Assn., has been followed for years. The association has set certain standards of manufacture and fabrication and, for the sake of uniformity, a pump with a given head capacity and a given column length will be sold by all manufacturers at nearly the same price. Price, therefore, is not the controlling factor.

Even though its efficiency was less at the design point, pump D was chosen for the well because: (1) Pump E, at high water level, would operate below the range of most economical production; (2) the head capacity curve of D more nearly follows the range of the most economical production; and (3) Pump D produces more water when it is needed in summer low-water period.

A new condition has recently been imposed and influences the final choice of the bowl assembly. The Southern California Edison Co., which is now producing a 50-cycle alternating current, proposes to change to 60-cycles. This change will require the complete redesigning of bowls in a large number of turbine pumps, and to meet it, all pumps that will be purchased hereafter must be designed to operate on 60 cycles, but with enough additional stages in the pump bowls to operate temporarily on 50 cycles. This will provide for a minimum of changes in the pump and prepare for making the change with all possible speed.

The company purchases the complete unit installed in the well and ready to operate when electrical and pipe connections are made. The responsibility for individual parts of the units rests entirely with the one manufacturer, who is required to guarantee not only the pump but the motor he furnishes with it. The efficiency test following the purchase is for over-all efficiency of the complete unit.

Specifications

The standard specifications provide for the majority of operating conditions, although special conditions, already mentioned, at times require revision of the standards. Generally, the specifications are as follows:

Bowls

All bowl castings, including top and bottom bearing housings, shall be of the best grade iron used by the manufacturer. The impellers shall be of bronze containing 85-88 per cent copper, 5-10 per cent tin and 2-5 per cent zinc, and may have 5 per cent lead if the same bronze is used for both impellers and line-shaft bearings. They shall be machined so that no rough surfaces are in contact with the water. The pump shaft shall be of stainless steel. The suction shall be 10 ft. of standard pipe with a standard "Greene" strainer.

Pump Column Assembly

The line shaft shall be of cold-rolled steel with surfaces polished and shall be in 10-ft. lengths joined with couplings to permit butting of the shaft within the coupling. The oil tubing shall be in 5-ft. lengths joined with bronze guide bearings to provide a bearing at 5 ft. intervals on the line shaft. The eduction pipe shall be of standard weight pipe, joined in 10-ft. lengths. Spider guides shall be installed within the column at the points indicated on the well survey diagram.

Design Point

A performance curve of the proposed pump shall be submitted, indicating the performance of the pump from shut-off to its point of cavitation and showing the over-all efficiency curve. This efficiency curve shall show the guaranteed field performance of the pump as installed, and shall be computed by relating the power of input to the unit to the theoretical water horsepower.

Pump Head

The pump head shall be the heaviest casting constructed by the manufacturer to receive the motor required for the pump, have a discharge nipple of the same diameter as the pump column, and be at least 2 ft. long.

Motor

The motor shall be of such size that at no point on the performance curve will the rated horsepower of the motor be exceeded. The motor shall be a 440-v., 50-cycle, 3-phase, vertical, hollow-shaft motor. It shall be designed to receive an adequate thrust bearing.

Manufacturers' Specifications

The manufacturer shall submit complete manufacturing specifications which show the sizes of various parts of the column and the number of stages in the bowls. The speed of operation of the motor shall also be given, as well as the name of its maker.

The value of these specifications has been proved through extensive use. They standardize and simplify the problems of selection and maintenance of deep-well pumps.

DISCUSSION—T. E. LARSON

Chemist, Illinois State Water Survey, Urbana, Ill.

Corrosion experiences with deep well turbine pumps may or may not be considered serious, depending on the local physical conditions and the maintenance care provided. The economics of proper maintenance sometimes permits a $400 replacement at a 100-ft. setting biennially, with no regard to excessive corrosion rates, or may necessitate a $6,000 expenditure to pull a pump at a 600-ft. setting and replace column pipe, shaft and shaft tube.

Galvanic Action

The ordinary galvanic attack is aggravated if two galvanic cells are set up in series in the installation. Such a situation exists if bronze impellers are used with cast-iron bowls and copper-alloy bearing-retainers are used with a water-lubricated steel shaft. In oil-lubricated pumps, the galvanic series is created if bronze impellers are used with cast-iron bowls and water is permitted to enter the enclosure tube above the bowls and to come in contact with the bronze bearings and steel shaft. It is obvious in these situations that current will flow from the iron impeller seats through the water to the bronze impellers and up the shaft to the bearings. At this point the current will leave the shaft and flow through the water to the bearing retainers or to the bearings and down the column pipe or enclosure tube to the bowls. A vicious cycle of galvanic action can be set up in this manner.

Water-Line Corrosion

Water-line corrosion is usually due to the existence of an "oxygen concentration cell" near the water line on the outside of the column pipe, and is adequately described in many texts.

Carbon Dioxide Corrosion

Carbon dioxide corrosion takes place at the high-pressure points in the pump bowls and between the column pipe and shaft tube. It causes noticeable pitting in the bowls, on the column pipe and shaft tube just above the bowls, and, to a lesser extent, just above the spiders.

A possible explanation of this type of corrosion is that it is caused by the release of gas bubbles in the water at the low-pressure points on the underside of the impellers and possibly at the entrance to the suction pipe. This can happen, particularly if rough edges are present. The gas is composed of nitrogen, water vapor and carbon dioxide, and can be expected in any ground water under artesian pressure. When formed, the gas bubbles pass through the turbine and column pipe and undergo changes in volume due to the changes in pressure that take place. They are carried through the pump into the column pipe.

A rapid increase in pressure gives the carbon dioxide a higher solution potential and, as it dissolves, the water film on the surface of each bubble becomes excessively acid through the formation of carbonic acid. As the gas bubble with its acidic surface film passes over metal, corrosive action takes place.

Stray Currents

Stray currents are known to exist at many installations. To what extent they may damage the pump will depend on whether the polarity at any point enhances or inhibits corrosion.

Prevention of Corrosion

Prevention of corrosion depends largely on the type of installation, the corrosion expected or encountered and the economics involved. Consideration of the savings effected by preventive methods should include the power saved by maintained pump efficiency and the trouble and cost of pulling the pump, as well as the cost of actual replacements.

B/W CONTROLLER CORPORATION

2206 East Maple Road — Birmingham, Michigan

ALL ELECTRIC, FLOATLESS LIQUID LEVEL CONTROLS

Hold Liquid Levels to Within ¼" Variations
No Vacuum Tubes
No Floats—No Moving Parts in Liquid
Unaffected by Pressure, Temperature, Acids or Caustics
Relay Can Be Located Any Distance From Electrodes

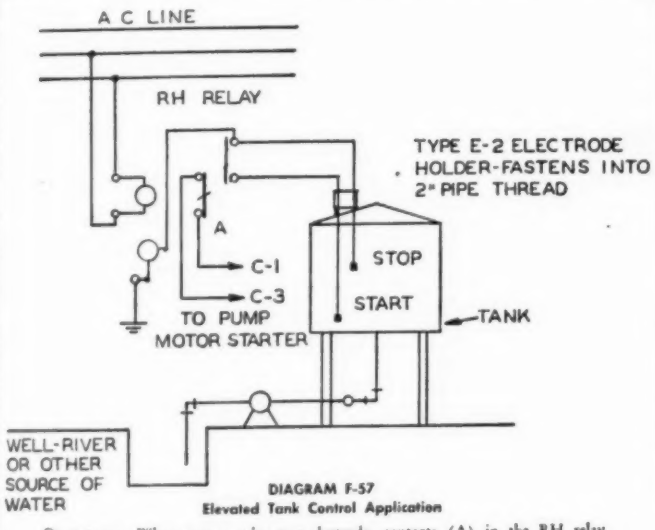


DIAGRAM F-57
Elevated Tank Control Application

OPERATION: When water reaches stop electrode, contacts (A) in the RH relay open to shut down the pump motor. When water reaches lower, or start electrode, contacts (A) close and pump motor starts.

GENERAL: This diagram shows a Type RH relay used to control the operations of a pump delivering water into an elevated tank. The electrodes in the tank, if levels are to be maintained fairly close to the top, may be brass rod. When great variations of levels are desired, it is recommended that electrodes, suspended from the E-2 holder on wire, be used in place of the rod.

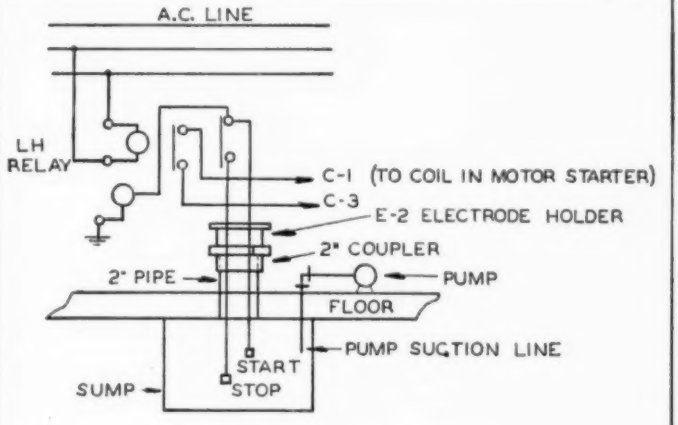


DIAGRAM F-55
Sewage or Sump Pump Application

Shows how short section of 2" pipe with coupler on upper end is installed through floor of pump-house so electrode holder can be installed in the coupler and electrodes suspended into the sump below.

This method seals off all gases from sump. It also permits electrodes to be easily removed for inspection, adjustment or cleaning.

The B/W System of Floatless Liquid Level Control was created in 1933, to meet the demand of engineers for controls that would eliminate once and for all the troubles caused by floats as well as moving parts in the liquid.

The B/W System consists of the patented B/W induction relay, and electrodes suspended from electrode holders.

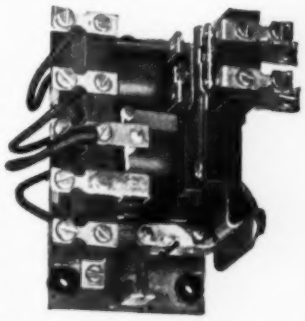
Because the B/W System uses no floats, vacuum tubes or moving parts in the liquid, and because the relay can be located any distance from the electrodes, it is the ideal system for use in water and sewage works.

The basic relays may be combined to form controls for special applications, such as alternating the sequence of operation of duplex pumps but operating both pumps in the case of flood conditions.

We have also perfected an ice-free electrode unit, in which a 350 watt immersion heater keeps the water in a 3" drop pipe warm and free from ice, even though ice forms on the side walls and over the top of the water in the tank.

Our many years of experience, not only in manufacturing but in working with water and sewage engineers in solving problems, have given us a wealth of information and engineering knowledge that should be valuable to you. The chances are that we already have the answer to many problems that have worried you. Let us know what they are. You will find us eager to cooperate with you.

B/W INDUCTION RELAY SWITCHES



Contain an electrode circuit holding switch connecting upper and lower electrodes in parallel when the armature is in contact with the pole faces. This permits the use of two electrodes, one above the other, to obtain any desired variation of levels from ¼" upward. All contacts are double break and are made of silver alloy. Connected to a permanent source of A.C. they draw a constant current of 4 watts, regardless of line or electrode circuit voltage. The illustration shows Type DH — one pole, double throw, for either "pump-up" or "pump-down" operation.

WRITE FOR NEW CATALOG

Our catalog contains full information on operation, induction relays, multiple pump controls, electrodes and electrode holders, magnetic contactors and starters as well as several pages showing typical application diagrams. Copy will be sent on request.

PRE-DETERMINING EFFECTIVE DOSAGE OF COPPER SULPHATE IN ALGAE CONTROL

A Simple and Practical Laboratory Test Developed for This Purpose

By WILLIAM D. MONIE
Superintendent, Commonwealth Water Co., Summit, N. J.

EVERY engineering problem, regardless of its complexities, is solved by a common sense application of fundamentals. The problem of algae control is no exception and must be solved by the common sense application of fundamentals pertaining to this problem. It is with these fundamentals which we call the A-B-C of algae control that this paper is concerned.

Canoe Brook Reservoir

The supply at the Canoe Brook station of the Commonwealth Water Co. is derived from a combination of artesian well water and a filtered surface supply. The surface water is pumped from a brook during wet seasons and stored in a reservoir approximately 204 acres in area, having an average depth when full of 11 ft., and a maximum capacity of 735 mg. In an average summer this reservoir constitutes a constantly decreasing but fluctuating volume of water, entirely exposed to light, with water temperatures reaching 80 degrees F.

The reservoir of the Commonwealth Water Co. presents three features which make the control of algae especially difficult. With a maximum depth of only 11 ft. when full, it cannot stratify during the growing season, so the nutrients available for algae development are used over and over again, giving maximum crops. Second, light at all times reaches the bottom where dormant stages of algae lying on the mud are quickly stimulated to activity whenever temperature and other factors are favorable. Finally, the reservoir is subject to marked fluctuations in its level. In consequence, the small bays and inlets, which are often the chief breeding grounds for objectionable algae, are frequently drained of their contents. Thus the entire reservoir is seeded again and again.

Algae control in this reservoir was indeed a problem. Records prior to 1939 show that it was not an uncommon occurrence to experience difficulty from luxuriant growths of algae, especially Anabaena and Aphanizomenon. In 1939, despite frequent treatments with copper sulfate from February through October, taste and odor trouble occurred in October because of abundant growths of Anabaena and Aphanizomenon.

A detailed study was then made of the A-B-C's of algae control with copper sulfate with especial consideration of our problem.

The A, B, C, of Algae Control

A—The ability to determine when it is necessary to treat a supply.

B—The ability to determine the correct amount of copper sulfate to apply when treating.

C—The ability to apply the treatment so that uniform distribution of the copper sulfate is obtained.

When to Treat

In determining when it is necessary to treat a supply, the most important governing point is a recognition of the fact that one must realize copper application is a preventive measure rather than a cure. Therefore, never wait for consumer complaints before treating; treat in ample time to *prevent* the complaints.

The best method of determining when it is necessary to treat a supply is by microscopic examination. When an organism is growing to such a point that it may cause trouble, daily microscopic examination and count should be made of samples taken directly from the reservoir. From the count and speed or rate of growth, it can be determined when the supply should be treated.

There are two points in the above paragraph which should be stressed: 1—Samples should be collected directly from the reservoir for microscopic examination. If samples are collected from a main, or after passage from a pump, delicate organisms are broken up and some become unrecognizable. 2—In the growing season daily microscopic examinations must be made. It is surprising how rapidly organisms increase in number when growing conditions are ideal. It is not uncommon to have an organism more than triple its numbers within one to two days.

From experience at the Canoe Brook reservoir certain upper limits of safety, beyond which treatment was necessary, were determined for each organism. These are—

Organism	Count*
Asterionella	1,000-1,200
Mallomonas	800-1,000
Anabaena	600- 800
Aphanizomenon	300- 600

*Total number of organisms in ten fields at a magnification of 100x.

It was decided to apply copper sulfate only when an organism reached these limits, as it had proven uneconomical to attempt control when the organism is just starting to increase.

Keep an Eye on the Thermometer

The growth of different types of organisms can be anticipated by the temperature of the water, especially surface temperatures. According to Nelson,[2] "approximately twenty years ago Dr. Setchell, botanist of the University of California, pointed out that there are definite ranges of temperature within which various flowering plants begin to grow and higher ranges at which they will flower. These critical temperatures were found to lie close to 5°, 10°, 15°, 20° and 25° C. (41°, 50°, 59°, 68° and 77° F.). His studies showed that as the temperature passed the critical point certain species were suddenly stimulated to activity. Hydrobiologists working with algae and protozoa are finding similar critical temperatures. Owing to the more gradual temperature changes which occur in the water, these ranges are more easily recognized and delimited than is the case with land plants."

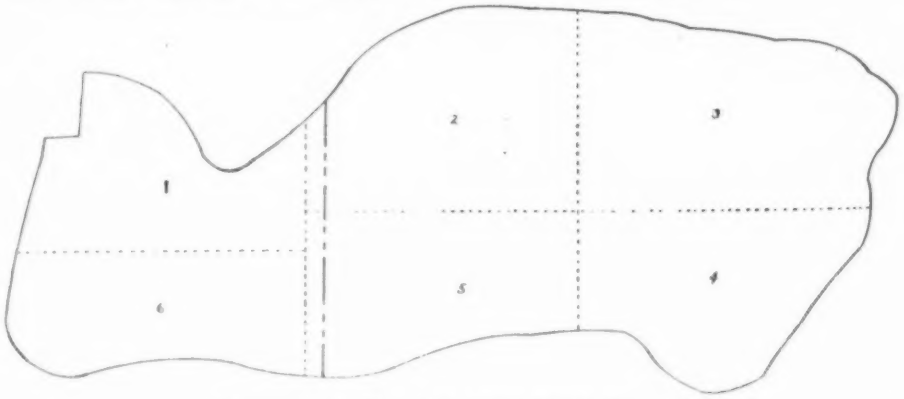
It has been our experience that different species of algae have started to grow at these temperatures. Therefore, as the temperature of the water reaches these critical temperatures get out your microscope and keep a close watch on the algae growth.

How Much Copper to Apply

It was with this factor—how much copper sulfate to use in treating—that we experienced the most difficulty. Many times what appeared to be an effective treatment three days after the application of the salt found an aftergrowth of the same organism within a week of treating that reached greater numbers than were present before the sulfate was applied.

Many Factors Govern Dosages

In regard to the question of the amount of copper sulfate to use in treating a supply, Hale[1] states: "Experience differs with waters of different composition, with temperature and with the amount of organism present as to the right dosage to apply for each organism. It is a waste of chemical to apply an insufficient amount. If a smaller dosage fails, the entire larger dosage must be applied at one time."



Diagrammatic Sketch of Canoe Brook Reservoir

The dotted lines show how reservoir is sectioned for purposes of sampling water and applying copper sulfate in correct proportion to water depth and algae concentrations. During algae growing season each section is sampled daily and given microscopic examination—believing that the old adage about an ounce of prevention being worth pounds of cure holds nowhere more pronouncedly than in algae control.

Therefore, it is *a waste of chemical to apply an insufficient amount,* just as it is a waste to apply an excess amount.

We used the table based on data by Moore and Kellerman, Whipple and others[1] as a starting point, and attempted to apply it to conditions existing at our plant. However, one of the organisms with which we experienced considerable difficulty was Aphanizomenon. The table gave a range of 1.0-4.2 pounds per mg. for the control of this organism. Furthermore, past experience showed that treatments of 1, 2, 3 and 4 pounds per mg. had all been effective for the control of Aphanizomenon at one time or another. We realized that if we treated for Aphanizomenon with 1 pound of copper sulfate per mg. when 4.2 pounds per mg. might be needed, the 1 pound per mg. treatment would be wasted, since the 4.2 pounds per mg. must be applied at one time to be effective. Likewise, if the 4.2 pounds per mg. was used and 1 pound per mg. would have done the work, then 3.2 pounds per mg. would be wasted.

With so many factors influencing the amount of copper sulfate to use in treating a supply, algae control would certainly be much more scientific if we had a test that would allow us to say definitely how much copper sulfate it was necessary to use to satisfy all conditions. In September of 1940 the author devised a simple, practical laboratory test to determine the amount of copper sulfate necessary to use in treating a supply of water regardless of its temperature and composition and, within certain limitations, regardless of the type and amount of organism present.

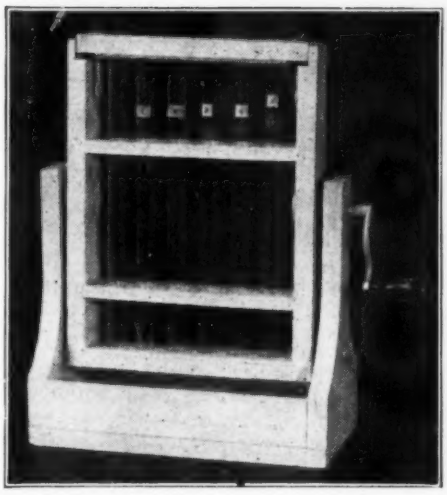
The "D. M." Test

It was found that the addition of certain amounts of copper sulfate to water containing algae resulted in an increase in the alkalinity. The amount of copper sulfate needed to bring about this increase in alkalinity was the correct amount to use in treating. After much experimentation the following test was developed.

The equipment and chemicals necessary for the test are as follows:

a. Six 50 ml. nessler tubes.
b. A copper sulfate solution of a strength that 2 ml. added to a liter of water equals a copper sulfate treatment of 1 pound per mg.
c. Phenolphthalein indicator.
d. 0.01136 N Na OH

To make the copper sulfate solution mentioned in b, dissolve 0.6 gram of the copper sulfate you use in 1 liter of distilled water. Dilute 100 ml. of this solution to 1 liter with distilled water. Two ml. of this final solution per liter of sample equals one pound of copper sulphate per mg., or 0.1 ml. per 50 ml. of sample equals one pound of copper sulfate per mg.



Tube Inversion Rack Used in "D.M." Test. (Honesdale, Pa., Water Co.)

Test Procedure

In each of six 50 ml. nessler tubes A, B, C, D, E and F, 50 ml. samples of the water to be treated are placed. To tube A, add 0.1 ml. of the copper sulphate solution (b) to equal a treatment of 1 pound per mg.; to tube B, 0.2 ml. of solution (b) is added to equal a treatment of 2 pounds per mg.; to tube C, 0.3 ml. of solution (b) is added to equal a treatment of 3 pounds per mg.; to tube D, 0.4 ml. of solution (b) is added to equal a treatment of 4 pounds per mg.; to tube E, 0.5 ml. of solution (b) is added to equal a treatment of 5 pounds per mg. To tube F, no copper sulfate is added. These samples are then mixed by corking and inverting approximately thirty times simultaneously.

To the nessler tube F (the blank sample) phenolphthalein indicator is added. If there is a negative amount of free carbon dioxide present, enough indicator is added until there is a faint but distinct pink color. Then the same amount of phenolphthalein is added to each of the other samples. The samples are compared and the tube with the deepest color is the tube containing the sample to which has been added the correct amount of copper sulfate to use in treating.

Influence of Carbon Dioxide

If there is free carbon dioxide present (and there usually is), three drops of phenolphthalein is added to each of the six samples in the nessler tubes after they have been mixed with the various amounts of solution (b) as described above. Then 0.01136N sodium hydroxide is added to the nessler tube F (the blank sample) until there is a faint but distinct pink color. The same amount of the sodium hydroxide is then added to the other five samples and the tubes are compared for color. The deepest color will be found to be in the tube containing the sample to which the most effective and economical amount of copper sulfate to use in treating has been added.

This test is practically the same as a free carbon dioxide titration. However, in the algae test it is simpler to have both the phenolphthalein and the sodium hydroxide in dropper bottles, as the equal amounts can be easily added to the sample tubes by counting the drops. 0.01136N sodium hydroxide is used simply because finer control can be maintained on the color. In waters with considerable carbon dioxide, 0.02272N can be used just as effectively.

It is important to note that the tube with the deepest color is always darker than the blank sample. Therefore, at the correct dosage of copper sulfate the water is more alkaline than it was prior to the addition of the salt. This result is clearly shown in the test irrespective of the fact that phenolphthalein is not a sensitive indicator. The puzzling factor of the entire test is the fact that at a certain concentration of copper sulfate dosage the alkalinity is increased, and then with an excess of copper sulfate the alkalinity decreases to approximately the same point as it was in the blank sample. Therefore the color in the tubes rises gradually with the dosage increase and after reaching a maximum the overdosage causes a lessening color development.

When the "D. M." test was first developed the author used a mixing machine with liter samples instead of the nessler tubes. However, the reaction in the test is so fast that the results can be obtained quicker with equal accuracy using the nessler tubes.

The accompanying picture illustrates a simple gadget made by the Honesdale Consolidated Water Co., Honesdale, Pa., for use in inverting the nessler tubes for mixing purposes. Although such an instrument is handy, accurate results are obtained when the mixing is done by hand.

If more than one type of organism is present in sufficient numbers it is possible to get two or more treating points by the "D. M." test. For example, Anabaena and Aphanizomenon were present at the same time in the water at Canoe Brook reservoir. The "D.M." test showed two distinct treating points, two pounds per mg. and four pounds per mg. To use two pounds per mg. would have been a mistake as only the Anabaena would have been destroyed, which would leave conditions perfect for the rapid increase of the Aphanizomenon.

Method of Coppering
Rowboat with outboard motor and copper sulfate applied from burlap bags, with quantity in the bags determining the dosage.

Proper Method of Copper Application

Proper distribution of the copper salt through the reservoir water is important to successful algae control. Knowledge of the first two steps for algae control—when

to treat, and how much salt to use in treating—would be of no value without proper application of the chemical. For example, if a four-pound per mg. treatment of copper sulfate is necessary, then the salt must be applied so that the water in all parts of the reservoir has received approximately a four-pound per mg. treatment. The deeper parts of the reservoir must receive in proportion more salt than the shallow parts. If this is not done, some portions of the water will be undertreated and the algae not killed in these parts will remain to re-seed the reservoir.

Here, again, a detailed study of conditions of each reservoir must be made and the method of application decided upon after careful deliberation. In the majority of lakes the best method of application is by dissolving the copper sulfate from burlap bags or perforated boxes attached to a boat. However, in some lakes and for certain types of algae some other method of application such as spraying either a solution of copper sulfate or broadcasting the pulverized dry salt may be more practical.

Knowledge of Reservoir Topography Important

In order to obtain proper uniform distribution of the chemical a knowledge of the reservoir bottom topography is an important consideration. If you do not have a contour map of the reservoir bottom, make one. The points for preparing such a map are easily obtained by soundings from a boat or from the ice in northern regions.

When the reservoir bottom topography is known it is a simple matter to section the reservoir into areas of approximately uniform depth. With this knowledge it is possible to apportion the salt in treating so that equitable application can be planned and made. In deep reservoirs usually only the top twenty feet need be considered in treating.

Method of Applying Chemical

At the Canoe Brook reservoir the treating is done by means of a boat propelled by an outboard motor. The chemical is placed in two burlap bags, one on each side of the boat, suspended from frames so that additional salt can be added to the bags to keep the amount of salt exposed to the water uniform. The strength of the treatments is regulated by the level of sulfate carried in the bags.

The conventional strip method is used in treating. After experimenting, the strips now used are approximately forty feet wide. This width of strip allows the reservoir to be treated in an eight-hour day with one boat. The same width of strips is adhered to regardless of the amount of salt per treatment, the amount of salt going into solution depending upon the amount exposed to the water.

In a case where a reservoir is so large that strips over 100 feet are necessary, more than one boat should be used in treating.

Results

The following table illustrates the results obtained over a seven-year period from 1939 through 1945 at the Canoe Brook reservoir. In five of these years the copper dosage was determined through the use of the "D.M." test.

Year	Treatments	Lbs. $CuSO_4$
1939	37	33,750
1940	7	11,250
1941	8	14,350
1942	3	6,200
1943	2	3,700
1944	3	5,200
1945	3	5,200

As shown by this table gratifying results were obtained by practical application of the fundamental A-B-C of algae control. From the last treatment in 1940 the "D.M." test was used in determining the amount of copper sulfate to use in treating.

There has not been a treatment where the amount of salt used was determined by the "D.M." test that was *not* successful. Additional success since 1941 is believed to be due to changes made in applying the fundamentals of when to treat and how to apply the salt.

One interesting observation during systematic use of the "D.M." test is that the amount of salt necessary to destroy certain organisms increases as the number of the organisms present increases until a certain point is reached and then the amount of salt required decreases as the organism continues to increase in numbers. This circumstance is unexplained.

References

(1) Hale, Frank E., "The Use of Copper Sulphate in Control of Microscopic Organisms." Phelps-Dodge Refining Co., New York. (Revised 1935.)

(2) Monie and Nelson, "Algae Control," *Jour. A.W.W.A.*, April, 1941.

CHART FOR CONVERTING GRAINS PER GALLON TO POUNDS PER MILLION AND THE REVERSE

Courtesy W. Donaldson and Fuller & McClintock, Engineers

POUNDS OF CHEMICAL REQUIRED PER HOUR FOR VARIOUS PUMPAGES & DOSES

PUMPAGE		DOSE - POUNDS PER MILLION GALLONS															
MILLION GALLONS 24 HRS.	THOUSAND GALLONS PER HOUR	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160
		DOSE - GRAINS PER GALLON															
		.07	.14	.21	.28	.35	.42	.49	.56	.63	.70	.77	.84	.91	.98	1.05	1.12
1.0	41.7	.417	.833	1.25	1.67	2.08	2.50	2.92	3.33	3.75	4.17	4.58	5.00	5.42	5.83	6.25	6.67
1.5	62.5*	.625	1.25	1.88	2.50	3.13	3.75	4.38	5.00	5.63	6.25	6.88	7.50	8.13	8.75	9.38	10.0
2.0	83.3	.833	1.67	2.50	3.33	4.17	5.00	5.83	6.67	7.50	8.33	9.17	10.0	10.8	11.7	12.5	13.3
2.5	104	1.04	2.08	3.13	4.17	5.21	6.25	7.29	8.33	9.38	10.4	11.5	12.5	13.5	14.6	15.6	16.7
3.0	125*	1.25	2.50	3.75	5.00	6.25	7.50	8.75	10.0	11.3	12.5	13.8	15.0	16.3	17.5	18.8	20.0
3.5	146	1.46	2.92	4.38	5.83	7.29	8.75	10.2	11.7	13.1	14.6	16.8	17.5	19.0	20.4	21.9	23.3
4.0	167	1.67	3.33	5.00	6.67	8.33	10.0	11.7	13.3	15.0	16.7	18.3	20.0	21.7	23.3	25.0	26.7
4.5	187	1.88	3.75	5.63	7.50	9.38	11.3	13.1	15.0	16.9	18.8	20.6	22.5	24.4	26.3	28.1	30.0
5.0	208	2.08	4.17	6.25	8.33	10.4	12.5	14.6	16.7	18.8	20.8	22.9	25.0	27.1	29.2	31.3	33.3
5.5	229	2.29	4.58	6.88	9.17	11.5	13.8	16.0	18.3	20.6	22.9	25.2	27.5	29.8	32.1	34.4	36.7
6.0	250*	2.50	5.00	7.50	10.0	12.5	15.0	17.5	20.0	22.5	25.0	27.5	30.0	32.5	35.0	37.5	40.0
6.5	271	2.71	5.42	8.13	10.8	13.5	16.3	19.0	21.7	24.4	27.1	29.8	32.5	35.2	37.9	40.6	43.3
7.0	292	2.92	5.83	8.75	11.7	14.6	17.5	20.4	23.3	26.3	29.2	32.1	35.0	37.9	40.8	43.8	46.7
7.5	312	3.13	6.25	9.38	12.5	15.6	18.8	21.9	25.0	28.1	31.3	34.4	37.5	40.6	43.8	46.9	50.0
8.0	333	3.33	6.66	10.0	13.3	16.7	20.0	23.3	26.7	30.0	33.3	36.7	40.0	43.3	46.7	50.0	53.3
8.5	354	3.54	7.08	10.6	14.2	17.7	21.3	24.8	28.3	31.9	35.4	39.0	42.5	46.0	49.6	53.1	56.7
9.0	375*	3.75	7.50	11.3	15.0	18.8	22.5	26.3	30.0	33.8	37.5	41.3	45.0	48.8	52.5	56.3	60.0
9.5	396	3.96	7.92	11.9	15.8	19.8	23.8	27.7	31.7	35.6	39.6	43.5	47.5	51.5	55.4	59.4	63.3
10.0	417	4.17	8.33	12.5	16.7	20.8	25.0	29.2	33.3	37.5	41.7	45.8	50.0	54.2	58.3	62.5	66.7
10.5	437	4.38	8.75	13.1	17.5	21.9	26.3	30.6	35.0	39.4	43.8	48.1	52.5	56.9	61.3	65.6	70.0
11.0	458	4.58	9.17	13.8	18.3	22.9	27.5	32.1	36.7	41.3	45.8	50.4	55.0	59.6	64.2	68.8	73.3
11.5	479	4.79	9.58	14.4	19.2	24.0	28.8	33.5	38.3	43.1	47.9	52.7	57.5	62.3	67.1	71.9	76.7
12.0	500*	5.00	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0	80.0
12.5	521	5.21	10.4	15.6	20.8	26.0	31.3	36.5	41.7	46.9	52.1	57.3	62.5	67.7	72.9	78.1	83.3
13.0	542	5.42	10.8	16.3	21.7	27.1	32.5	37.9	43.3	48.8	54.2	59.6	65.0	70.4	75.8	81.3	86.7
13.5	562	5.63	11.3	16.9	22.5	28.1	33.8	39.4	45.0	50.6	56.3	61.9	67.5	73.1	78.8	84.4	90.0
14.0	583	5.83	11.7	17.5	23.3	29.2	35.0	40.8	46.7	52.5	58.3	64.2	70.0	75.8	81.7	87.5	93.3
14.5	604	6.04	12.1	18.1	24.2	30.2	36.3	42.3	48.3	54.4	60.4	66.5	72.5	78.5	84.6	90.6	96.7
15.0	625*	6.25	12.5	18.8	25.0	31.3	37.5	43.8	50.0	56.3	62.5	68.8	75.0	81.3	87.5	93.8	100.0

* Exact Values

1 grain per gallon = 143 pounds per million gallons = 5.95 lbs. per hour for each million gallons
0.70 " " = 100 " " " " " = 4.17 " " " " " "

Example: What weight of Chemical must be fed each hour to give a 70 lb dose for a pumpage of 8.0 M.G.D.
Opposite 8.0 M.G.D and under 70 find 23.3, which is the correct weight.

CHEMICAL WEED CONTROL*

By R. F. Goudey
San. Engr., Dept. of Water and Power, Los Angeles, Calif.

THE use of chemicals for the economical control of weeds in and around reservoirs is rapidly becoming important because it eliminates sources of tastes and odors in water and results in less annoyance and grievance to consumers. It is a subject on which there has been too little study and research and about which there is much misunderstanding. Moreover, there has not been a clear evaluation of important and pertinent factors applying to the water works practice. It appears to be nature's intent eventually to make land from every body of shallow water, and in this transformation water weeds play an important role. Aquatic weeds appear to be gaining headway in all parts of the country.

Considerable progress has been made in the past 50 years in the development of chemicals and methods of application for controlling land weeds. Little of this experience has been used by the water works profession, yet it is the best answer to the control of shore line growths and all types of vegetation rooted in water but growing largely above the water surface, referred to hereinafter as "emergent growths." Progress in controlling strictly aquatic growths by chemical means has been confined to the past ten-year period and has been largely restricted to controlling weeds in irrigation canals, ditches and reservoirs. The use of such chemicals in domestic reservoirs has been limited because, first, the fear of consumers' complaints of chemical tastes following periods of treatment; and, second, reports that in some cases fish casualties have been high. Recently there has been a move to render such chemicals less odor producing.

Rather than draw a hard and fast line between land weeds and strictly aquatic weeds, an effort will be made in this paper to coordinate these once considered separate fields, because the chemicals now used for both purposes are quite similar, the effects on plant growths in general are identical and the technical problems of control are the same. Some compounds used are poisonous and others must be handled with special precautions, but all should be studied carefully to determine their possible effects on water quality; and, even in the case of land weed control, the effect, if any, on underground water quality must no longer be overlooked. The water works operator must be aware of weed control practices by private and governmental operatives on the watersheds in order to safeguard the water quality of both surface and subsurface water supplies.

The older processes of oiling, burning, raking, dragging and chaining still have their special applications. For instance, when a reservoir can be lowered, the exposed weeds can be sprayed with a heavy fuel or diesel oil and allowed to dry for about ten to fourteen days. Then a light oil can be sprayed on it and everything burned. Vegetation along ditches can be seared with burning heavy oil, allowed to die and later be burned completely by a flame thrower. Generally, such methods are only temporary expedients and are time consuming and costly. The use of chemical methods is far more scientific and satisfactory. During the war, chemical weed control received an impetus because of the shortage of labor and the scarcity of oil. Yet, chemical control of weeds is neither simple nor easy. It cannot be considered child's play. Under no circumstances should novices experiment. Already there has been too much unnecessary killing of cattle, destruction of fish, creation of tastes and neglect in evaluating the most important factors involved which threaten further development. For these reasons conflicting reports are being circulated, prejudices are being established and it is becoming increasingly difficult to obtain the truth.

Land Weed Control

Land weeds are of great concern to agriculturists, and enormous quantities of herbicides are used annually. The federal government, through its U. S. Department of Agriculture and Soil Conservation Service, is vigorously promoting programs to suppress undesirable growths on range lands, pastures and drainage ditches. In Texas, major emphasis is on the eradication of Mesquite and Juniper, which, in California, are valuable desert shrubs. The Civil Works Division of the War Department has used herbicides to control salt cedar (*Tamarix gallica*) in canals and river channels of the Southwest. State departments of agriculture throughout the country are fully informed on chemical weed control measures and are openly recommending expanding use. The U. S. Forest Service uses herbicides on fire breaks and in the suppression of irritant shrubs. Chemicals are used in the control of weeds along railroads, utility rights-of-way, at airports, tennis courts and parking lots. The use of herbicides is steadily increasing.

The use of chemicals for land weeds can be divided into three categories: (1) where it is the intent to sterilize the soil temporarily to permit no growth whatever; (2) where all plants treated are killed but the soil remains suitable for crop production, and (3) where chemicals are added to kill specific growths, even though the chemicals are simultaneously applied to other growths. The water works man is interested in all three types of control. Certain areas, such as dirt roads, tops of earth dams and the zone between high and low water level of reservoirs, should be made sterile and be kept barren. Whereas, in the care of the downstream slopes of hydraulic fill dams, the banks of earth canals, the vicinity of reservoirs and around utility yards, vegetation of the right type should be encouraged and pest weeds only should be controlled. Dandelions in lawns, poison oak or poison ivy near roads can be controlled by selective action of specific herbicides.

So wide is the field of herbicides for land weeds that no effort will be made in this paper to list or identify weeds which have been controlled, or to give complete information on the types of chemicals used. One of the best references for chemicals used in land weed control is given by Robert A. Stetson in an article on chemical weed killers,[1] which includes a bibliography of 36 other articles. Other practical references include "Weed Control"[2] and "Weeds of California."[3] Full directions are supplied by manufacturers for mixing and spraying and general instructions as to rates of application per acre are furnished. These instructions are apt to be most misleading. Here is where experience comes in and where carefully kept records and photographs of work before and after treatment are valuable. Also, the reader is advised, in general, to treat during the growing season, but experience gained the hard way only will lead to final successful practice.

Some of the basic chemicals used for land weed control, covering a very wide variety of trade names not mentioned in this report, include:

1. Inorganic Chemicals

a. *Arsenicals.* Arsenicals sterilize soil, kill plant roots, are toxic to animals and man and are the most widely used herbicides to date. Sodium arsenite is the basic ingredient and compounds usually average 5 per cent arsenic. Water works men have refrained from using arsenicals, but they have been unduly cautious. So long as the arsenic content in the delivered water does not exceed 0.05 ppm., there need be no concern in the use of these compounds where they can be used to advantage.

b. *Salt.* Plain salt (sodium chloride) applied 1 lb. per gal. per sq. yd. sterilizes soil temporarily, that is, until it is washed out by rain.

c. *Sodium chlorate.* This has been used in a great variety of formulas. Used alone in 2-4 per cent concentrations by weight, or 4-8 oz. per gal. on 10 sq. yd., it is very effective on a great variety of weeds, and is toxic neither to animal nor man. However, it is highly dangerous from a fire standpoint. As soon as the water evaporates, it ignites readily. Even clothes splashed with the chemical when dried will start to burn. Obviously, the addition in various amounts of such substances as calcium chloride, borax, vanadium, pentoxide and manganese salts has been largely to offset and prevent firing. Dyes have been added so the operator can see where the chemical may have splashed on burnable materials. Where destroyed weeds are later to be raked up and burned, the fire repellents will defeat easy burning, unless rains in the meantime have washed the chemical from the weeds.

d. *Sulfates.* Sulfuric acid is useful in killing trees by the "ring" method. Copper sulfate in a 10 per cent solution, with 1 gal. treating 250 sq. ft., is good in soil sterilization work. Ferric sulfate and ammonium sulfate in the ratio of 3 to 2, applied at a rate of 7 oz. to 1 sq. yd., is specific for pearlwort.

e. *Carbon bisulfide.* This has been used largely on bindweed. It is explosive, inflammable and dangerous to store or transport.

f. *Borax.* Borax is the chief ingredient of Nox-Weed, one of the newer formulas for solutions containing it, and is particularly effective against willow trees. It adds measurable amounts of boron to the water supply and must be used with caution where the water is used to irrigate citrus and tropical trees. Impure deposits of borax are used by direct scattering on soil.

2. Petroleum Fractions

Kerosene, gasoline, coal oil and diesel oil have been used as herbicides and still

*From the *Jour. Amer. W. W. Assn.*, Feb., 1946. Reprinted by permission of the A.W.W.A.

have important roles. The oiling of reservoir banks every three years is good practice, provided the banks are steep and no attempt is made to lay down excessively heavy blankets of oil in shallow coves. Weeds which have been killed by oil obviously can be easily burned before they are thoroughly dried out. Oil, in general, does not translocate too far into root systems. It does, however, kill buds beneath the bark. Willow trees up to 1-in. trunk diameter can be killed with oil which, applied to the leaves, is carried to the roots; however, plants which reproduce by sending up new shoots are not controlled.

3. Organic Chemicals (other than petroleum fractions)

a. *Thiocyanates.* These are less active than chlorates but are safer. A dose of 2 lb. per square rod kills most weeds. Ragwort is destroyed by a 2.5 per cent solution, 200 gal. of which are applied to an acre.

b. *Furfural.* This is usually a kerosene (45 parts), xylol (45 parts) and furfural (10 parts) mixture applied at the rate of 500 gal. per acre, and is satisfactory for dandelions and deep-rooted perennials.

c. *Ammonium sulfamate.* This is nontoxic, is not a fire hazard and is specific for poison ivy and poison oak, but breaks down to a fertilizer. This is of an advantage to agriculturists but a disadvantage to the water works man because it aggravates algal growths. Sulfamic acid, though a little harder on equipment, has been found equally satisfactory in parallel test runs and does not break down to a fertilizer.

d. *Dinitro-ortho-cresol and its derivatives.* This is one of the new compounds.

e. *Dichlorphenoxacetic acid or its salts.*[4] These substances in very low concentrations were, previous to 1945, considered growth-regulating (hormone) substances, but it has been discovered that in stronger amounts plants literally grow themselves to death. These compounds are formed by the reaction of dichlorphenol (a chlorinated phenol) and acetic acid. The chlorine is combined with the second and fourth carbon atoms of the phenol molecule and the compound for short is called 2,4-D. It is insoluble in water and liquid preparations (9.6 per cent 2,4-D) are usually made with an emulsifier, such as carbowax, for dilution to a 0.1 or 0.2 per cent solution for spraying. The salts in powdered form dissolve in water and wetting agents are added to secure uniform coverage of plants sprayed. Manufacturers recommend a dosage rate of 200 gal. (1 per cent 2,4-D) per acre for most weeds, with consideration given to the type and amount of the growth. Actual practice indicates better results with 0.5 per cent instead of the basic 1 per cent rate. The effect of 2,4-D on plants is weird and unnatural. The stems and leaves twist and bend and the root system overgrows itself. Four to eight weeks may be required for the weeds to die. Except for grass, 2,4-D kills everything, even the morning glory with its deep roots sometimes reaching depths of 20 ft., which heretofore have been most difficult to destroy. The 2,4-D compounds have successfully killed artichoke thistle, bent grass, blue lettuce, bull thistle, Canadian thistle, chickweed, chicory, clover, cockleburs, dandelion, fennel, gaura, Jap honeysuckle, klamath weed, knotweed, mallow, milk thistle, morning glory, mustard, pigweeds, plantain, poison oak, puncture vine, purslane, ragweed, Russian knapweed, sow thistle, sumac, water grass, white top cress, wild blackberry, wild oats, wild radish and yellow star thistle.

In some instances particular care in the use of wetting agents and thoroughness in spraying are required. This is the most promising chemical for "emergent growth" control. Whether the compounds sterilize soil, which is a controversy among agriculturists, is of no concern to the water works profession. In fact, there are cases where sterility of the soil would be advantageous. It should be realized that there is much to be learned about the use of 2,4-D. Its effect on lateral roots at different stages of the plant's life cycle remains unknown. Several sprayings are needed for most types of plants to obtain a 100 per cent kill.

Commercial brands of 2,4-D include En-Dow-Weed, Dow A-510, Weed-Tox, Weedone, Phenox Weed Killer, Slayz-Weed, Slayz-Weed 60, Weedicide, and Dee-Cee-Pee, as furnished by six competing companies.

f. *Dinitro-ortho-secondary butyl phenol.* This chemical was developed to replace oil during the war, and is said to have better action on certain weeds. The author has seen a test plot of wild parsnip fairly well eliminated with a spray of 6 per cent of the chemical in 85 per cent oil along the McNally Canal in Owens Valley, treated July 26, 1945.

The author has had experience with all types of chemicals above mentioned, and recommends that careful consideration be given to the selection of the chemical best suited for each particular job. Different chemicals have their advantages and these should be capitalized. If ground is to be sterilized, certain chemicals are best. If destruction by translocation (absorption by the leaves and carrying of the chemicals to the roots) is required, the 2,4-D compounds are, undoubtedly, superior. In some cases, 2,4-D compounds could be used on broadleaf weeds and mixtures of various other chemical sprays could be used for devil grass on the same areas. Likewise, some chemicals have specific disadvantages. If animals and fish are to be protected, toxicity must be considered. Proper selection must be made from a wide variety of spreading or wetting agents to secure coverage of spray on foliage. Experience and judgment remain paramount.

So far as the experience of the Department of Water and Power of Los Angeles is concerned, good results have been obtained with Nox-Weed on willow shrubs; with 2,4-D mixtures on wild parsnip and general weeds, and with ammonium sulfamate on poison oak.

There is much to be learned when it comes to applying chemicals. Ordinarily, plants should be sprayed when young and vigorous, with equipment having sufficient pressure to give thorough atomization, and at the same time strike the vegetation with considerable force. It is recommended that spraying with sulfamate be preceded with a water fog spray. In most other instances, the spray should be applied just after the morning moisture has evaporated from the leaves in order to prevent dilution and sliding off of the chemical. If plants are sprayed too early, or with too strong a concentration, the tops may appear to be quickly killed back, but sprouts may appear later. If sprayed too late in the season, results may be erratic and seeds may not be killed. Certain manufacturers specify that 70° F. is about the best treating temperature. Probably the best criterion to insure good results is to treat when the plant is in its prime and is actually growing.

Mixtures of 2,4-D dry powder with various oils and different weed chemicals can be used to advantage on trees, large shrubs and in special problems. One operator used diesel oil fortified with 2,4-D powder in the ratio of 1 lb. of powder to 100 gal. of oil. Since the 2,4-D powder dissolves in but a few oils, a combination of 1 to 2 lb. of powder to 96 gal. of water and 4 gal. of oil has been suggested. In this case, mechanical agitation must be provided. Trees are best killed by cutting them close to the ground, frilling them with a ring at ground level, and pooling with fortified oil, as described above, or with 10 per cent chlorate or 5 per cent arsenite.

Great care must be taken to protect perennials near where weeds are being sprayed with 2,4-D compounds. Orange and lemon trees have already been inadvertently killed. In one instance, an irrigation ditch drained of water was sprayed with 2,4-D compounds and no trouble resulted when water was subsequently run through it onto garden crops, but when water from the same ditch was later spread onto a cotton patch the cotton plants were affected.

Careful consideration must be given to the effect of 2,4-D compounds on creating odors in water supplies, as some of the 2,4-D compounds contain 45 per cent dichlorphenol. Until further investigations have been made all vegetation sprayed by 2,4-D compounds should be cut, raked and burned, preferably before it can be rained upon, to destroy any remaining chemical. One 2,4-D manufacturer in starting up a new location spoiled several batches, which resulted in the discharge of some dichlorphenol into a sewer system leading to an activated sludge plant, which in turn discharged into a practically dry river channel. This effluent which seeped into the ground in the vicinity of wells spoiled the water supply for more than 6,000 consumers. The resultant dilution was less than one to ten million. The question immediately arises concerning the purity of the 2,4-D compounds as offered on the market. They certainly should be free of appreciable amounts of dichlorphenol. Commercial 2,4-D compounds diluted to one to ten million have a noticeable odor, and the threshold dilution is about one to one hundred million. It is thus apparent that care must be taken so far as the wholesale use of such compounds by the public on watershed areas is concerned.

Emergent Weeds

Emergent weeds retard flows in streams, aqueducts and canals, and provide harbors for troublesome protozoal and algal growths. Generally, they have been reported as clogging ditches, plugging drains, fouling lakes, endangering swimming, interfering with fishing and causing excessive transpiration losses. That they cause serious tastes in water supply by their own disintegration, and from secondary algal growths which they support, is a fact which cannot be lightly set aside. Growths should be controlled early before they literally take over their environment.

Emergent weeds are rooted in mud. They grow in water and support leaves and flowers 1 ft. or more above the water surface. The most troublesome types, and by no means a complete list, are identified according to Jepson,[5] as shown in Table I.

Until recently, it has been difficult to cope chemically with emergent weeds. Cattails and tules, and their roots, were successfully killed on Nov. 24, 1943, at Upper San Fernando Reservoir by spraying with Nox-Weed, yet tules similarly sprayed at Bouquet Reservoir in November, 1944,

TABLE I

Common Name	Botanical Name
1. Arrowhead Family—Duck Potato	*Sagittaria*
Tule Potato	*S. latifolia*
2. Bur-Reed Family	*Sparganiaceae*
Bur-Reed	*S. eurycarpum*
3. Cattail Family	*Typha*
Common Cattail	*T. latifolia*
4. Evening Primrose Family	*Onagraceae*
	Jussiaea
Yellow Water Weed	*J. Californica Jepson*
5. Grass Family	*Gramineae*
Ditch Grass	*Paspalum*
Ditch Grass	*P. larranagai*
Joint Grass	*P. distichum*
6. Pickerel Family—Mud Plantain	*Pontederiaceae*
	Heteranthera
Water Hyacinth	*Eichornia crassipes*
Water Stargrass (also submerged)	*H. dubia*
7. Rush Family	*Juncaceae*
Common Rush	*J. patens*
8. Sedge Family	*Cyperaceae*
Water Sedge	*C. aquatilis*
Club-Rush and Bulrush (many species)	*Scirpus*
Common Tule	*S. acutus*
9. Water Plantain	*Alismaceae*
Water Plantain	*Alisma*
	A. plantago
	Damasonium
	Echinodorus
	E. cordifolius
10. Water Milfoil Family	*Haloragcae*
Mare's Tail	*Hippurs vulgaris*

were killed but new tules appeared from underground shoots immediately adjacent to parent plants. Rushes were killed in July, 1945, at Girard Reservoir by use of the same chemical. The new 2,4-D compounds have been tried on all types of emergent growths, but it will not be till next year that definite proof that roots have been killed will be available. Johnson grass, the bane of all irrigators, is efficiently killed by 2,4-D compounds.

Sedges and rushes have been killed by cutting plants below the water line and treating with many types of chemicals, such as cloroben, copper sulfate and arsenicals, but this method now appears antiquated.

It is the general consensus of those who were questioned by the author that in treating emergent weeds the use of 2,4-D compounds excels all, and that emergent growths should be treated as if they were land weeds. With ordinary care, all emergent weeds can be easily and readily controlled. Cases of failure have been largely due to neglect to follow up with subsequent treatments and to expecting too much from a single treatment.

Aquatic Weeds

Aquatic weeds include algae, mosses and plants. Since algae and mosses, particularly angel's hair or horsetail moss, can be readily controlled by use of copper sulfate or Benoclor, they are not classified in this paper. They must be controlled because they create major problems in clogging ditches and canals, in restricting carrying capacity of canals and aqueducts, in clogging screens at intakes and in creating odors and tastes in domestic water supplies.

Aquatic weeds, other than emergent growths, divide themselves naturally into three groups: (1) plants leaning on the water for support by use of pads and flowers; (2) plants entirely submerged except for blossoms which may need to mature in the air; and (3) free-floating plants without roots permanently located in mud. Principal offenders, according to Jepson's system of classification, are shown in Table II.

It is to be noted that water weeds cover a wide range of complexity so far as structural features are concerned. Some, like *Chara*, a stonewort, are intermediate between typical algae which they structurally resemble and the higher plants, the general form of which they simulate. They remove calcium carbonate from the water and produce a limy formation on the leaves and stems which makes them quite rough to touch. Their reproduction is simple and is affected by a pear-shaped ovary containing one egg adjacent to a male organ which resembles a brightly colored microscopic orange, both of which can be seen with the aid of a hand lens at the base of the branches. This organism is easily destroyed. On the other hand, some of the weeds, like the *Potamogetons*, are very highly specialized and, in fact, are trees rooting in as much as 35 ft. of water. They remain submerged except for the flowers which, in most varieties, must reach the air and depend upon flying insects for fertilization. Some *Potamogetons* may propagate by as many as five different methods —bud, seeds, joints, tubers and roots. Some weeds, on the other hand, flower and fruit entirely below the water surface. These complications must be considered in the ultimate eradication of water weeds. It is therefore important for one using chemicals for weed control to be able to identify the more common species, to know their reproducing and growing characteristics and their habits of growth. In this connection, the chemical constituents of the water, the type of mud in which the plants take root, the temperature of the water and the amount of water motion probably bear more on the problem of successful chemical control of weeds than has been recognized so far.

Chemicals Used in Aquatic Weed Control

Four types of chemicals have been used for aquatic weed control, namely sodium arsenite, copper sulfate, chlorine and Benoclor.

Arsenicals

Commercial meta-arsenite ($NaAsO_2$), containing 4 lb. of arsenic oxide (As_2O_3) per gallon, is being used widely in fish ponds, private ponds and lakes. Obviously, arsenicals are poisonous to man and animals, and their use must be restricted to places where the concentrations of arsenics reaching consumers shall be accurately controlled so as not to exceed 0.05 ppm. Arsenicals are sprayed onto the surface of the water to give a dose of about 1.0 to 2.0 ppm. of arsenic, with two to three follow-up treatments required. The following growths have been successfully treated with arsenic: *Ceratolphyllum demersum, Potamogeton interior, Elodea canadensis, Heteranthera dubia.* Fish and fish food are not affected

TABLE II

1. *Plants leaning on the water with pads and blossoms:*	
a. Water-Lily Family	*Nymphacaceae*
Pond Lily	*Nymphaea*
Water Shield	*Brasenia*
2. *Plants entirely submerged except for blossoms which may or may not mature in the air above the water level:*	
a. Frog's Bit Family	*Hydrocharitaceae*
Water Weed or Anacharis	*Elodea canadensis*
b. Stonewort Family (Muskgrass)	*Chara*
c. Mustard Family	*Cruciferae*
(Above water in summer)	*Radicula*
Watercress	*R. nasturtium-aquaticum*
d. Pondweed Family	*Naiadaceae*
(1) *Pondweeds*	*Potamogeton*
Thick Leaf Pondweed	*P. lucens*
Leafy Pondweed	*P. foliosus*
Slender Pondweed	*P. pusillus*
Sago	*P. compressus*
Eel-grass Pondweed	*P. pectinatus*
(2) *Pondweeds* (Wigeon Grass)	*Ruppia*
Ditch Grass	*R. maritima*
(3) *Pondweeds*	*Zannichellia*
(Flower and fruit under water)	
Horned Pondweed	*Z. palustris*
e. Water-Milfoil Family	*Haloragcae*
(1) Western Milfoil	*Myriophyllum hippurioides*
(2) American Milfoil	*M. spicatum*
3. *Surface and free-floating plants:*	
a. Bladderwort Family	*Utricularia*
Common Bladderwort	*U. vulgaris*
b. Duckweed Family	*Lemnaceae*
Duckweed (Star Duckweed)	*Lemna*
Gibbrous Duckweed	*L. gibba*
Smaller Duckweed	*L. minor*
c. Hornwort Family	*Ceratophyllaceae*
Hornwort-Coontail	*C. demersum*
d. Parsley Family	*Umbelliferae*
	Hydrocotyle
Water Pennywort	*H. ranunculoides*
e. Purslane Family	*Portulacaceae*
(Rooted in shallow water)	
Indian Lettuce	*Montia*
Water Chickweed	*M. fontana*

by dosages usually employed.[6] At Toluca Lake, after repeated treatments with arsenicals, it appeared that pond lilies, which were killed at first, developed resistance to subsequent treatments.

Copper Sulfate

Copper sulfate has been used widely to control aquatic growth, although little is understood about its use. One outstanding accomplishment was the almost complete annihilation of *Potamogeton pectinatus* in Ivanhoe Reservoir (capacity, 34 mil. gal.; area, 9 acres) of the Los Angeles water system by the addition of 4,000 lb. of copper sulfate on May 16, 1945. Tons of "hay" were removed when the growth sloughed off near the roots and were blown ashore. The copper sulfate had been uniformly distributed in pea-sized crystals over the flat bottom of the reservoir. Yet, when a similar treatment for the same type of growth was given to Pressure Break Reservoir (capacity, 34 mil. gal.; area, 7.3 acres) in August, 1945, results were negative. It was later in the season, the reservoir bottom was not flat and the previous continual feeding of small concentrations of copper may have built up a copper tolerance in the plants. *Potamogeton* was successfully killed at Upper San Fernando Reservoir (capacity, 660 mil. gal.; area, 83 acres) on Aug. 7, 1944, when the aqueduct at Dry Canyon Reservoir was treated with 7.038 lb. of copper sulfate primarily to control slime growths in the aqueduct. The kill was most astounding. Copper sulfate sprinkled dry over reservoir bottoms before refilling kills roots and seeds of *Potamogeton*. This was proved at Silver Lake Reservoir where all water weeds were successfully controlled for seven years. After the last cleaning, no treatment was administered and growths are now appearing. There is much to be learned so far as the use of copper sulfate is concerned.

Chlorine

Two experiments were made in July, 1924, one at Ivanhoe Reservoir and the other at the spreading grounds of the Los Angeles River supply, with chlorine gas injected into the mud and sand under heavy growths of *Potamogeton*. Chlorine bleached and killed adult plants but root buds germinated subsequently. The chief drawback to the use of chlorine gas is the difficulty of applying the chemical to the exact spots needing treatment.

Chlorinated Hydrocarbons

The use of liquid chlorinated hydrocarbons for aquatic weed control was inaugurated by the Cloroben Corporation of New Jersey.[7] The first compound is known as Benoclor No. 3 Regular, and is used in treating reservoirs. Miscible Benoclor No. 3 Special and Benoclor No. 3-C are used for running water where tastes and odors are not to be considered. The former, which is less stable, is immiscible and is used for domestic supplies whereas the latter stands up with better emulsification for use in irrigation reservoirs and ditches. New types are being developed to minimize taste problems.

Benoclors which are "still" runs of chlorinated benzene are mainly tri-chlorinated benzenes. They have a pungent odor, are non-corrosive, non-inflammable, non-toxic, relatively heavy (sp. gr. 1.45) and are sprayed under water, which produces a white milky cloud. Plants readily absorb and adsorb the chemical with great avidity and translocate it to vital parts. The leaves deteriorate and the cloroplasts dissolve into the oil of the chemical applied. Within 24 hours plants collapse and in four to five days turn white. Animal life is destroyed, provided it does not get out of the way of the advancing treatment.

Aquatic weeds vary in their response to Benoclor treatment. *Chara* and "water weed" are two types that are easily killed. Sago pondweed, coontail moss, horned pondweed and water milfoil are intermediate in response. Parrot feather requires a surface spray only at a rate of 500 gal. per acre. The emergent weeds are more difficult when treated with Benoclor. Cattails and tules have been killed when previously cut beneath the surface of the water. Yellow water weed, ditchgrass *(Paspalum distichum)*, sedges and rushes have been killed, but higher dosages are required for them.

Application of Chlorinated Hydrocarbons

Chlorinated hydrocarbons are applied as a spray either from a fixed point into a canal where it treats the water passing by or from spray equipment on boats treating reservoirs or lakes. Any type of pump and air compressor is suitable (ordinarily 1½-hp. air-cooled gasoline engine directly connected to a 3-gpm. Viking pump), provided the size, type and number of nozzles are selected which will give a reasonable degree of dispersion for the quantity which should be applied per unit of time.

Nozzles with screened openings 0.02 to 0.04 in. (Spray Equipment Co.) are ordinarily spaced 2 ft. apart. Preferably, the chemical should be sprayed about 1 ft. above the tops of the submerged weeds and at least 4 in. below the water surface. The approximate dose for lakes is 15-50 gal. per acre. Present practice in treating irrigation ditches has been greatly modified. First, the water level is lowered to a minimum. Second, the first treating station is selected 750 ft. upstream from the infested area. Third, in a ditch with a top width of 12 ft. and a bottom width of 7 ft., a dose of about 11 gal. per mile is used, with two-thirds being applied at the first station and continued for one hour. Fourth, a second station is started one-half mile downstream to reinforce the chemical blanket to its original intensity, usually taking about one-sixth of the total dose. Fifth, a third station another half mile downstream repeats the same process. Such a treatment cleans 2 miles of ditch. Water so treated may be disposed of by dilution into a larger canal, by being run to waste or by absorption by a mile or more of untreated ditch before it is used for irrigation purposes. The exact dose per mile obviously depends upon the amount of weed growth present, type of soil and other factors. *Anacharis* has been killed with 1,000 ppm. of Benoclor applied for one hour, or 4,000 ppm. applied for fifteen minutes. A balance must be established between the dose concentration and the contact period allowed.

Toxicity

Benoclor is not toxic to birds or animals.[8] Livestock refrain from drinking water containing noticeable amounts of Benoclor, and animals which drink water containing sufficient amounts of Benoclor to taste appear not to be affected. Benoclor will kill fish if care is not taken in the application of the chemical. In lakes and reservoirs, the Benoclor should be treated from the shore outwards in such a way that it will not trap fish in coves or sections of shallow water. In some instances the growth near the shore line can be cut, thereby scaring the fish to deeper water. Benoclor is toxic to crayfish and clams. It has no effect on human beings, and quantities of water containing a high concentration appear not to be too objectionable from the standpoint of taste and odor. The aromatic, or medicinal, odor is not overly objectionable and in high dilutions Benoclor gives the water a "clean" taste.

Los Angeles Experience

Benoclor has been used at Dry Canyon and Bouquet reservoirs on a growth of Potamogeton pectinatus. Original failures were due to the use of dosage rates which later proved too low. The record based on data furnished by H. F. Cahill, superintendent of the Los Angeles Aqueduct, Southern Division, is as follows:

Dry Canyon Reservoir (Capacity, 440 mil.gal.; area, 59 acres)

November, 1942—100 gal. were used on marginal treatment at a rate of 18 gal. per acre. The outflow was 301 fps. Results were negative.

Dec. 6, 1942—100 gal. were added to the east cove at the rate of 15 gal. per acre. The reservoir had been by-passed with no outflow. The kill was about 50 per cent. On this occasion, owing to the density of the weeds, 28 fish, 2 to 4 in. in length, mostly carp, were killed.

June, 1943—Experiments were made on four separate square plots on the submerged portions of the dam, using 2 gal. per plot, or approximately 30 gal. per acre. The flow through the reservoir was 476 fps. The center plot had a 75 per cent kill, but the plots nearest moving water were less successful, clearly showing the effect of dilution.

Aug. 27-September, 1943—The main coves of the entire reservoir were treated, wherever visible growths could be detected, with a dose of 35 gal. per acre. Results were good in all water shallower than 8 ft. Beyond this depth the percentage of kill decreased rapidly as the water deepened. Tastes were observed by consumers taking water directly from this reservoir for a period of 48 hours following each treatment. The complainers were not adamant; in fact, they were somewhat apologetic; nevertheless, they were justified. The fact that some of the chemical reached them indicated that dispersion was excessive.

June 21-28, 1945—The growths in deep water nearest the channel and near the upper end were found to be as bad as ever, and 150 gal. were added at a rate of 40 gal. per acre. The maximum amount added per day was 50 gal. This was reduced to 35 gpd., and finally to 15 gpd. Complaints were still received, even with the 15-gpd. application, and treatment was terminated to stop further complaints.

Experience definitely proved that the original dosage rate of 15 gal. per acre, as recommended by the manufacturer's representative, was too low. The author feels that a dosage rate of 50 gal. per acre would have produced better results. The second lesson gained by this experience was that any domestic reservoir treated with Benoclor should be bypassed and no dilution be permitted for three to four days.

Bouquet Reservoir (Capacity, 5,100 mil.gal.; area, 420 acres)

This reservoir had a very heavy growth at the northeast end in water up to 40 ft. in depth, and patches were spotted along most of the entire shore line.

July 1-22, 1943—A dose of 35 gal. per acre was applied to the entire shore line where weeds were found. The total amount of chemical used was 600 gal. The reservoir had no water flowing in or out. The kill was 90 per cent, with a noticeable improvement in the shallow areas over the steeper banks.

Sept. 20-22, 1943—With the reservoir 4 ft. lower, 150 gal. of chemical was used on patches which were too deep to reach during the July treatment. The dose of 35 gal. per acre was only approximated. The kill was about 90 per cent.

While some of the spots were completely eliminated, the area which had been the worst was, by September, 1945, rapidly nearing its original condition. This may be due in part to the fact that both treatments were made with the water level 15-20 ft. below normal, and weeds rooted or seeded above the treated line had a chance to grow as soon as the reservoir water level was brought back to normal. It was observed that some of the original growths occurred in water which was normally 35 ft. deep.

Irvine Ranch Experience—Peter's Lake (Capacity, 330 mil.gal.; area, 64 acres)

Peter's Lake is an irrigation reservoir with no domestic use. The main growth was *Potamogeton pectinatus,* along the shore line principally, which was so thick that a rowboat could not be oared through it. There was a secondary growth of *Chara.* A special hand paddle boat had to be rigged up for treating purposes.

Late summer, 1944—During the late summer, 75 gal. of Benoclor was added on test areas along the shore with a dose set at 45 gal. per acre. The kill was over 90 per cent but, because the weeds had already flowered and had dropped their seed, it was decided to postpone general treatment until the following spring.

June-July, 1945. With the growth not yet up to the water surface, 250 gal. of chemical were added at an exact rate of 50 gal. per acre up to water depths of 16-18 ft. Previously, the chemical had been added just barely below the surface. The second treatment was made by lowering the nozzles right down to a foot above the growing tops. The kill, as observed by the author on Sept. 13, 1945, was remarkable. An estimate of 95 per cent is conservative. One cove appeared not to have been as carefully treated as the rest of the shore line. No check was made on tastes and odors. About 10 lb. of fish were killed because of their apparent inability to remove themselves from entangled growths as chemicals were applied. The growth of *Chara* was killed with a dose of 15 gal. per acre. Scattered *Chara,* patches of minor consequence, were observed returning.

The chief lessons of this experience are:

(1) *Potamogeton pectinatus,* which is one of the most difficult of all weeds to control, can definitely be killed by a Benoclor dose of 50 gal. per acre when accurately applied over the plants in the growing season before flowers set.

(2) Dilution with new water must be kept to a minimum, and at least four days' storage is desirable.

(3) Roots of the growths were thought to have been killed, which up to this time had not been accomplished.

Imperial Valley

In 1943 test runs were made at Blythe and Yuma, and by the Imperial Irrigation District in Imperial Valley to work out operating procedures to use Benoclor for keeping irrigation ditches clean.[9] The Imperial Valley Irrigation District services over 3,000 miles of canals and irrigation ditches, covering over 400,000 acres of irrigated land. A canal, six miles in length, which had overflowed at 45 fps., when it should have safely carried 100 fps., was selected for treatment. The flow was reduced to 10 fps. and run to waste, while a six-hour treatment was made. The water level dropped 1½ ft. Roots, however, were not killed, and it was claimed that treatments were only to delay or retard growth with gradual reduction of aftergrowths following treatments during the growing seasons. To date about 5,000 gal. of Benoclor per year have been used in Imperial Valley.

Salt River Valley

The Salt River Valley Irrigation Districts irrigate over 340,000 acres. About 3,500 gal. per year are used in ditch weed control. Richard Bennett, city engineer of Phoenix, in response to inquiries of the author, substantiates the following:

1. Benoclor is beneficial for algae, moss and rabbit's foot grass.

2. Benoclor does not kill the roots of all the *Potamogeton* plants (at least so far as the short method of treatment is concerned).

3. There is no adverse effect on the lands irrigated.

4. Some of the worst canals are treated six to eight weeks apart, but the average control is 2½ months in length.

5. Because of the high cost of chemicals, treatment is restricted to small distributing ditches with mechanical methods still being employed on the larger canals.

6. Water star grass, which is particularly bad in local canals, has been killed (including the root system) by exceedingly heavy Benoclor doses in standing sections with two hours' contact.

It would appear that still heavier chemical doses or longer contact periods should be tried out in place of treating every six to eight weeks in an effort to attack root systems more vigorously. It would also appear that the continual reseeding from the growths in the main canal, together with the growths from broken sections caused by mechanical cleaning in the main canals, indicates that sooner or later the source of the trouble itself must be eliminated by chemical treatment of the main canals themselves. It is said that the present high cost of the chemicals prevents this being considered. Yet it is obvious that treatment in this instance should start at the Stewart Mountain detention dam, where growths are prolific. They do not cause trouble so far as operation is concerned at this location, but are the main source of seed and sprouting in lateral ditches.

Winslow

The Santa Fe Railroad operates a six-mile ditch near Winslow for an engine water supply. Weeds became so prolific that the carrying capacity was seriously affected. After several unsuccessful attempts to regain capacity by treating with copper sulfate, George Davenport, water supply engineer for the Santa Fe Railroad Co., during July, 1945, used 100 gal. of Benoclor. Sufficient capacity of the ditch was restored to meet the existing emergency.

Yakima, Wash., U. S. Bureau of Reclamation, Tieton Division

A test run was made in June, 1945, on five miles of ditch, using 50 gal. of Benoclor with one-hour contact. Of this amount 30 gal. were added at the first station and 20 gal. at a second station, one mile downstream. The growth was largely "water weed," with some sago pondweed. Results are said to have been good.

Miscellaneous

Distributors for Cloroben state that there has been interested use of this chemical by various irrigation companies in New Mexico, Texas, Utah and Washington. In California it has been adopted by the Miller & Lux Land Co. in San Joaquin Valley and by irrigation districts in Modesto and Turlock. The Montana Fish and Game Commission employs Benoclor to make surveys of non-game fish.

A review of the literature indicates that Benoclor has been used at a number of locations, as follows:

1. *Echo Lake near Westfield, N. J.*[10] Treatment was administered to minimize water weeds for the benefit of boating and bathing with doses varying from 12 to 14 gal. per acre. Studies indicated considerable improvement in odor reduction four to six days after treatment.

2. *Cranberry Lake, Sussex County, N. J.*[11] Treatment was administered to clear up the lake from excessive water weeds, largely *Potamogeton robbinsii,* which resulted in improved fishing conditions for the public. This lake covers 195 acres, 15 per cent of which was so overgrown with liliaceous vegetation as to be unnavigable. At least 35 acres were treated with reasonable success with an application of 750 gal. of chemical at a cost of $3,000.

Economics Involved

Chemical treatment of land, emergent and water weeds is economically justified. Probably the most expensive chemicals for land weeds are the 2,4-D compounds. It is estimated that the cost per acre per one application, using retail prices, is $10 per acre, but if raw materials are purchased and mixed it may not exceed $5 per acre. An estimate for chemically treating a 500-ft. strip around 1,199 electric transmission line towers with Nox-Weed was received from a bidder quoting $32,000 for chemicals at 17 cents per gallon, or $6 per acre, and $34,500 for labor in difficult terrain requiring 237 days.

The mechanical costs of removing cattails, tules and other emergent growths from canals vary from $1,000 to $2,000 per mile. Mechanical cleaning and dredging involves interruption of service, gives but temporary relief and often accelerates reseeding and rerooting. Chemical treatment is far cheaper and less cumbersome.

Mechanical cleaning of canals and ditches to remove aquatic growths below the water line varies from $150 to $600 per mile. Chemical treatment, on the other hand, is about $30 per mile per treatment. On a yearly basis, the total cost is $50 per mile, which is a fraction of that for mechanical cleaning.

The cost of treating reservoirs with Benoclor at $2.75 per gal. is high, amounting to $137.50 per acre. This is over twenty-five times the cost for land weed control with 2,4-D compounds. One justification for the high cost of Benoclor is that so far there has been only a limited use of it, and, until the quantity used increases, production cost in all probability cannot be lessened. Ortho-dichlorbenzene, which in preliminary results may be 80 per cent as efficient as Benoclor, costs only $40 per acre. The use of this material, however, would be an infringement on patent rights. Undoubtedly chemical costs for aquatic weed control may be expected to be reduced as the demand for chlorinated carbons increases.

Evaluation of Problems Involved

Successful weed control for land, emergent and water weeds requires:

1. Accurate identification of vegetation to be controlled.
2. Knowledge of budding, blossoming, fruiting and environmental habits.
3. Recognition of stage of growth of plants present.
4. Selection of chemical best suited for each type of plant, and decision whether soil should or should not be sterilized.
5. Determination of dose and time of contact.
6. Consideration of dilution and storage factors where aquatic growths are concerned.
7. Consideration of type of soil and density of growth, and in the case of water weeds the mineral quality of the water and nature of the soil underlying the water.
8. Accurate application of chemicals with proper wetting, emulsifying or spreading agents, and in the case of water weeds the placing of the chemicals directly over plant tops.
9. Attention to all hazards, such as toxicity to man and animals and fire and handling hazards.
10. Preventive measures to conserve fish life.
11. Determination of resistivity built up by specific types of plants after repeated treatments with the same chemical.
12. Consideration in the case of water weeds of water movement and limnological factors.
13. Proper housekeeping methods in cleaning up debris after treatments have killed the plants.
14. Careful application to avoid tastes and odors in domestic supplies, both surface and subsurface, and before and after subsequent chlorination.
15. Taking of photographs and keeping of accurate records on treatment results.
16. Conducting chemical examinations to trace residual chemicals in the water supply, resulting from land or water treatment for weed control.
17. Patience and persistence in following up with subsequent treatments.
18. Rigid control of specifications of chemicals used, particularly in reference to impurities which may cause odors in water supplies.

Conclusions

Land and water weeds can be economically controlled by the use of chemicals, provided such work is properly supervised and intelligently applied.

Land weeds and water emergent weeds are generally best controlled by the new 2,4-D compounds, but other chemicals have specific advantages for different purposes.

Submerged aquatic weeds are generally best controlled with chlorinated hydrocarbons, employing higher doses than previously recommended (up to 50 gal. per acre), allowing much longer contact periods (up to four days) than formerly, and by observing necessary factors to avoid complaints of odors and tastes from consumers.

References

[1]Stetson, Robert A. Chemical Weed Killers. *Soap & San. Chem.*, **21**:7:104 (1945).

[2]Robbins, Crafts and Raynor. *Weed Control.* McGraw-Hill Book Co., Inc., New York (1944).

[3]Robbins, W. W., Bellue, Margaret K., and Ball, Walter S. Weeds of California. Supervisor of Documents, State Printing Office, Sacramento, Calif. (July, 1941.)

[4]Harvey, W. A. Growth Regulating Substances as Weed Killers. College of Agric., Div. of Botany, Davis, Calif. (July 2, 1945.) Released in mimeographed form.

[5]Jepson, W. L. *Manual of the Flowering Plants of California.* Sather Gate Bookshop, Berkeley, Calif. (1923).

[6]Surber, Eugene W. Controlling Vegetation in Fish Ponds with Sodium Arsenite. U. S. Dept. of Commerce, Bureau of Fisheries, Investigation Report No. 11 (1932).

[7]Seydel, Herman. A New Method of Weed Control in Lakes and Reservoirs. *W. W. & Sew.*, **85**:7:688 (1938).

[8]Huffman, W. T. Toxicity of Benoclor 3S for Sheep and Cattle. Salina Expt. Sta., Salt Lake City, Utah (Feb. 2, 1945). Released in mimeographed form.

[9]Hartzog, W. E. Ditch Vegetation Is Removed Without Stopping Water Flow. *Western Constr. News*, **19**:5:74 (1944).

[10]Gibbons, Mortimer M. The Use of Benoclor 3 in Potable Water Supplies. *W. W. & Sew.*, **87**:5:231 (1940).

[11]Wilber, C. P. Aquatic Weed Control. *Parks & Recreation*, **25**:4:296 (1942).

A helpful reference on the further identification of water plants is:

Fassett, N. C. *Manual of Aquatic Plants.* McGraw-Hill Book Co., Inc., New York (1940).

Cost of Water at Stated Rates per 1,000 Gallons

Cubic Feet	U. S. Gallons	COST PER 1,000 GALLONS						
		6 Cents	8 Cents	10 Cents	15 Cents	20 Cents	25 Cents	30 Cents
20	150	$ 0.009	$ 0.012	$ 0.015	$ 0.022	$ 0.030	$ 0.037	$ 0.045
40	299	0.018	0.024	0.030	0.045	0.060	0.075	0.090
60	449	0.027	0.036	0.045	0.066	0.090	0.112	0.135
80	598	0.036	0.048	0.060	0.090	0.120	0.150	0.180
100	748	0.045	0.060	0.075	0.112	0.150	0.187	0.224
200	1,496	0.090	0.120	0.150	0.225	0.299	0.374	0.449
300	2,244	0.135	0.180	0.224	0.336	0.449	0.561	0.673
400	2,992	0.180	0.239	0.299	0.450	0.598	0.748	0.898
500	3,740	0.224	0.299	0.374	0.561	0.748	0.935	1.122
600	4,488	0.269	0.359	0.449	0.673	0.898	1.122	1.346
700	5,236	0.314	0.419	0.524	0.786	1.047	1.309	1.571
800	5,984	0.359	0.479	0.598	0.897	1.197	1.496	1.795
900	6,732	0.404	0.539	0.673	1.010	1.346	1.683	2.020
1,000	7,480	0.449	0.598	0.748	1.122	1.496	1.870	2.244
2,000	14,961	0.898	1.197	1.496	2.244	2.992	3.740	4.488
3,000	22,441	1.346	1.795	2.244	3.366	4.488	5.610	6.732
4,000	29,922	1.795	2.393	2.992	4.488	5.984	7.480	8.976
5,000	37,402	2.244	2.992	3.740	5.610	7.480	9.350	11.220
6,000	44,883	2.692	3.590	4.488	6.732	8.976	11.220	13.464
7,000	52,364	3.141	4.189	5.236	7.854	10.472	13.090	15.708
8,000	59,844	3.590	4.787	5.984	8.976	11.968	14.961	17.953
9,000	67,325	4.039	5.385	6.732	10.098	13.464	16.831	20.197
10,000	74,805	4.488	5.984	7.480	11.220	14.961	18.701	22.441
20,000	149,610	8.976	11.968	14.961	22.442	29.922	37.402	44.882
30,000	224,416	13.46	17.95	22.44	33.662	44.88	56.10	67.32
40,000	299,221	17.95	23.94	29.92	44.883	59.84	74.80	89.77
50,000	374,026	22.44	29.92	37.40	56.104	74.80	93.50	112.20
60,000	448,831	26.92	35.90	44.88	67.325	89.76	112.20	134.64
70,000	523,636	31.41	41.89	52.36	78.546	104.72	130.90	157.08
80,000	598,441	35.90	47.87	59.84	89.766	119.68	149.61	179.53
90,000	673,247	40.39	53.85	67.32	100.986	134.64	168.31	201.97
100,000	748,052	44.88	59.84	74.80	112.21	149.61	187.01	224.41
200,000	1,496,104	89.76	119.68	149.61	224.42	299.22	374.02	448.82
300,000	2,244,156	134.64	179.53	224.41	336.62	448.83	561.03	673.24
400,000	2,992,208	179.53	239.37	299.22	448.83	598.44	748.05	897.66
500,000	3,740,259	224.41	299.22	374.02	561.04	748.05	935.06	1122.07
600,000	4,488,311	269.29	359.06	448.83	673.25	897.66	1122.07	1346.49
700,000	5,236,363	314.18	418.90	523.63	785.45	1047.27	1309.08	1570.91
800,000	5,984,415	359.06	478.75	598.44	897.66	1196.88	1496.10	1795.32
900,000	6,732,467	403.94	538.59	673.24	1009.87	1346.49	1683.11	2019.73
1,000,000	7,480,519	448.83	598.44	748.05	1122.08	1496.10	1870.12	2244.15

SOME PRACTICAL ASPECTS OF HANDLING CHLORINE

By CHRIS F. BINGHAM*
Virginia Smelting Co., Norfolk, Va.

THIS paper is intended to record various practical experiences in chlorine handling, but the writer quotes freely from an A.W.W.A. 1935 report on Chemical Hazards, where deemed advisable, and recommends that those interested procure a copy of the journal containing it.

Properties of Chlorine

Chlorine gas is approximately two and one-half times as heavy as air at normal temperature and pressure, and hence, leaking chlorine, tends to settle and collect in low places and on the floor of an enclosed room.

Chlorine is neither flammable nor explosive. The dry gas does not attack iron, copper, or lead at ordinary room temperature. However, in the presence of moisture it is very corrosive and combines readily with most metals except those classed as the "noble" metals and special alloys. It is important to note that even the dry gas becomes very corrosive at temperatures above 300 degrees F. and is likely to become so at temperatures as low as 195 deg. F.

Chlorine Lines

Rubber and the noble metals are sufficiently resistant to the action of wet chlorine to be satisfactory material to handle either the moist gas or water solutions. Liquid chlorine in itself cannot, however, be used with hard rubber. During the last year and a half plant tests have been made in Richmond to determine the resistance of asbestos-cement pipe to chlorine solutions. As a result, the prechlorination and copperas-chlorine solution systems have been rebuilt using two and one-half inch "Transite" Class "B" pipe and Class "S" elbows. So far, this installation has given excellent service, the only difficulty encountered was due to its brittleness and the lack of sufficient mechanical support—a few sections of the pipe being broken by strains before adequately supported. The chlorine solution seems to "wet" the inside of the pipe to a depth of ⅛ to 3/16-inch and then stop, no further change was noted in the experimental installation or in the new permanent installation after two months of heavy use.

Extra heavy iron pipe with wrought iron fittings and litharged joints should be used for the chlorine pressure lines. Litharge that has been opened for some time seems to form a carbonate coating on the particles which result in a never-hardening and oily joint compound which will allow the joint to leak probably. Only new litharge is recommended. Care taken in the correct installation of pressure feed lines is a thousand fold repaid. Ammonia valves (of steel) have been used in the chlorine pressure lines at Richmond with satisfactory results, but where possible the standard Chlorine Institute ton container valve has been used because of its convenience, economy and superior construction. In general chlorine needle valves should have either Hastelloy "C" or Monel Metal stems, and joint valve bodies may be constructed of steel, brass or Hastelloy "C."

Soft copper tubing connections (cadmium plated) are used in connecting the one-ton chlorine containers to the piping system. We specify that a small wrench "hold" be milled on the bushing on the tubing, to allow holding the tube at the joint during tightening of the coupling. This, to prevent wringing off the tube at that point. The tubing becomes quite hard and rigid after continued service, but its ductility may be renewed by heating slowly to a dull red heat and quenching in water—the customary method of copper softening.

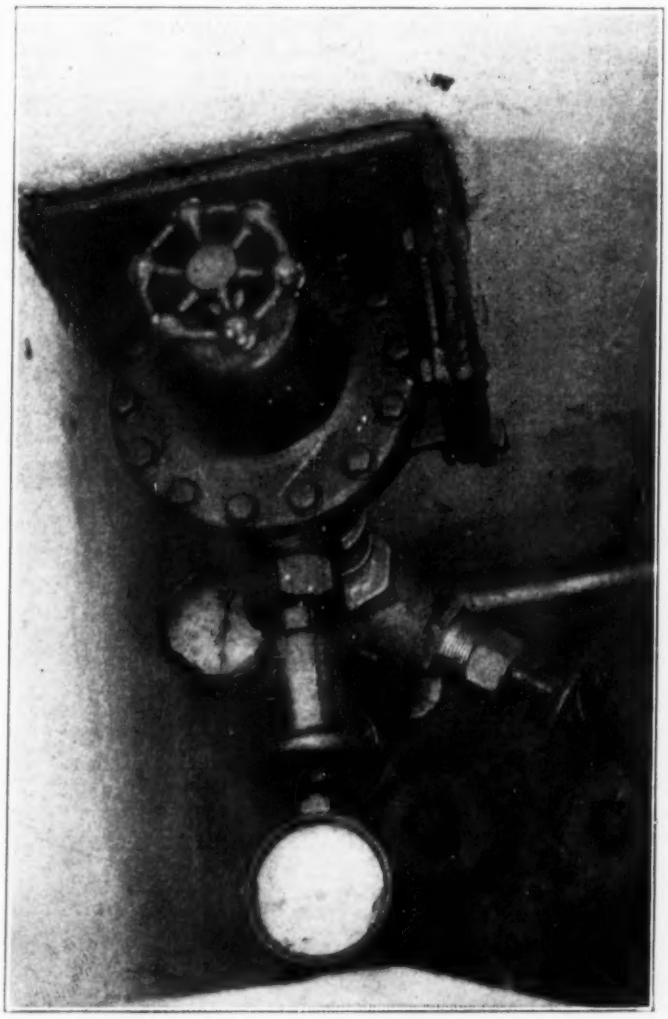
Hard drawn copper fittings and pipe of the "Streamline" type also have been used with essentially *pure* silver as the solder instead of the regular solder, furnished for such pipe, which chlorine attacks. A silver coin will serve as satisfactory solder. High copper content brass fittings have been used with this type of pipe also and seem to work entirely satisfactorily.

*Plant Supt., Div. of Filtration, Dept. Public Utilities, Richmond, Va., at time of preparation of this article.

Avoiding Condensation Troubles

The gas feed lines should, if possible, always be warmer than the chlorine containers to avoid condensation (reliquefaction of chlorine) and consequent problems. These lines should also be run on a continuous upgrade from the containers in order that the condensed liquid chlorine will flow back to the containers. Such theoretical conditions cannot always exist practically and, in cases where this is impossible, drip-legs should be provided at every low point on the pipe line—especially so near the chlorinators. Blow-off cocks or other bleeding arrangements are not recommended since they are both dangerous and unnecessary. If the drip-legs are so located that the room temperature does not keep the condensate vaporizing at a satisfactory rate, additional heat may be applied by warming with a 100-watt electric bulb permanently installed beneath the leg. The size of the leg varies with the conditions, but it is recommended to be 1¼ times as large as the volume of the pipe line leading from the chlorine container to the leg.

Chlorine reacts with grease and oil to form voluminous frothy substances; with gasoline and other petroleum distillates to form solid complex chlorinated hydro-carbons. Alcohol and ether, even in traces, are converted to solid waxy hexachloroethane. It is important, therefore, that all grease, moisture, etc., should be thoroughly removed from chlorine lines during their erection. Methane derivatives, chloroform, wood alcohol, and carbon-



One of the Reducing Valves (Looking Down) on the Chlorine Feed Lines. It Is Located on the Manifold Just Beyond the Containers in the Outside Gassing Chamber

tetrachloride are the only safe chlorine equipment cleansers to employ.

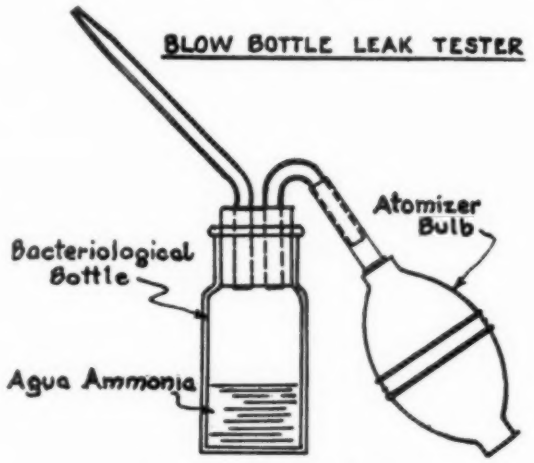
Whereas, drip legs are very helpful, condensation in chlorine lines should be avoided. If the gas leaving the container drops only a few degrees in temperature it will condense into a liquid in the feed lines and find its way into the chlorinators, with its consequent troubles. This condition can best be avoided by reducing the pressure at the containers to the lowest point permissible for the proper operation of the machines. In fact, if the line pressure be kept at 40 pounds per square inch or less no condensation can occur in the lines except at extreme cold temperatures. In Richmond, by keeping the reducing valves (in duplicate) set at 35 pounds per square inch, no liquefaction has resulted, although the chlorine feed lines are 400 feet long and the containers are in compartments outside of the plant which get quite warm in summer and also are artificially warmed in cold weather—an ideal condition for condensation in the feed lines.

Chlorine, in distilled water, at 49.2 deg. F. will form chloral-hydrate, commonly referred to as "chlorine ice." This condition is frequently found in the trays of vacuum type chlorinators during cold weather; but may be overcome by placing an electric light under the tray of the chlorinator. At the same time, reducing the water flow through the tray is also helpful. Since the solubility curve is a very sharp one a rise of only one or two degrees of the water is sufficient to do away with the trouble.

Container Temperatures and Pressures

The per cent of container volume occupied by liquid chlorine in the containers, when loaded to the limit permitted by the Interstate Commerce Commission regulations, is such that at 153.9 deg. F. the cylinder becomes completely filled due to the expansion of the liquid chlorine. Liquids do not have the compressibility or cushioning effect possessed by gases hence any further increase in the temperature will cause enormous pressure in the containers. For this reason, fusible plugs are provided which are intended to soften at slightly above this temperature and thus relieve the dangerous pressure. It is important, therefore, to keep the cylinders below this temperature regardless of the amount of chlorine that they may contain. Experience at the Richmond plant justifies this warning.

There are several practical precautions suggested by the above facts. Cylinders should never be directly heated by flame, steam or even electrical means that can exceed 160 deg. F. To avoid such hazard, warm air from the building is blown through an underground pipe to the containers which are housed in compartments outside of the plant. Secondly, a full cold chlorine cylinder has a lower pressure than one at room temperature; hence, if they are connected together as on a header, the cold cylinder will actually draw in chlorine. If the valve is then closed the overload cold cylinder may cause trouble when it becomes warm, even to room temperature. Hence, cylinders should be brought to about the same temperature before being connected together. As another example, the re-loading of containers thought to be empty, is absolutely forbidden unless under technical supervision.



The Chlorine Leak Tester

If gas is drawn from a container, the pressure within the container will be reduced. If a constant supply of gas at constant pressure is to be maintained, then heat must be applied to the liquid in the container. The more rapidly the gas is removed, the more rapidly heat must enter. This is usually accomplished by increasing the room temperature. If instead of adding heat, the container is cooled—the pressure falls. This is why a leaking cylinder should be cooled as rapidly as possible. Different opinions exist as to the maximum rate that gas may be drawn from cylinders. Experiments at Richmond have indicated that as much as 800 pounds per day may be drawn from the standard one ton container, in the summer when indoors, with pressure maintained on the gas line at not less than 30 pounds per square inch. However, 400 to 450 pounds per day is about the maximum successful continuous rate of supply from these containers. With the 150 pound cylinder the rate is about 30 pounds per day. Increasing the room temperature and providing air circulation will increase the rate of gassing. Especially so with a full cylinder because there is then a large area of the liquid exposed to the sides of the warmed cylinder. Adequate air circulation is a considerable aid in maintaining sustained gassing rates.

Handy Light Weight Safety Truck for Cylinder Handling (Courtesy Carl Leipold, Winnetka, Ill.)

Handling Containers

Containers are built of steel and may be safely handled with care. Dropping or bumping containers is extremely dangerous, and facilities used in handling should be carefully arranged to prevent such rough treatment. Hoisting is to be avoided if possible. Low, rubber tired trucks are preferable if conditions allow. A rubber tired light weight hand-truck for 150 pounds cylinders, first used by Carl Liepold at Winnetka, Ill., plant has proven both safe and convenient. The overhead monorail system used in Richmond for ton containers, involves the use of a lifting hook used to reduce space and suitable for low head operation on such a system. Out of doors storage is provided in racks, the enclosed section being the warmed gassing chamber. The maximum chlorine temperature yet found in these stored containers is 108 deg. F. or a pressure of 160 pounds which is amply safe. In warmer climates it may be well to shield stored containers from direct heat of the sun.

Chlorine may be safely stored indoors. Having the containers in operation mounted near the control machine undoubtedly has its advantages. In small installations, having in storage or in

use only a few 150 pounds cylinders, this risk is not serious and the practice is to be recommended, but when larger quantities of chlorine are necessary the advantage of the out of door storage and gassing chamber, with only the chlorine feed lines and the machines in the building, is certainly evident.

Ventilation Facilities and Leak Handling

When storage and operating containers are indoors adequate and reliable ventilation is essential. Exhaust air ducts draining air from the room should intake at the *floor level* and a fan forcing air into the room should drive the chlorine atmosphere directly out of the building. Where steam is available, a suitably designed ejector system, with discharge to a sewer or stack, is perhaps the best disposition of the escaped chlorine.

The use of neutralization tanks containing caustic, or attempting to stop a leak by spraying water on the leak, or cooling with ice and salt, while theoretically correct are of doubtful practical value. Practically it has been found at the Richmond plant that the best disposal is by submerging the cylinder, as for example, in the raw water flume, or other convenient large body of flowing water. "Dry Ice" (solid carbon dioxide), is the only method used successfully in cooling a cylinder to stop a leak by sufficiently reducing the gas pressure.

A suitable number of gas masks, of a design approved by the U. S. Bureau of Mines, should be readily available in a convenient location, and all employes should be trained in the correct procedure in putting on the masks. There is quite a prejudice among a large number of operators against the use of a mask in stopping small leaks. Contrary to general statements otherwise, that chlorine exposures produce no cumulative effects, the writer has noted cases of men repeatedly exposing themselves to small concentrations and have ended up with irritations such as results from a heavy concentration. It is well to note that the life of a canister type gas mask of the soda lime-activated charcoal type, depends not only upon the extent to which it is put to active service, but upon the storage conditions. Such canisters deteriorate rather rapidly when left open to the air and, therefore, the bottom opening of the canister should be kept sealed with the plug or disc supplied by the manufacturer. The useful life of a canister cannot be predicted and a fresh canister should always be available. Canisters should be replaced periodically, regardless of use.

Remember three simple rules in using a gas mask:

1. Never use where there is any danger of a deficiency of oxygen.
2. The life of the canister is an unknown quantity.
3. Any gas mask job is a *two man* job.

Even small chlorine leaks are dangerous and should be stopped immediately. A chlorine leak may be readily located by means of aqua ammonia. The best procedure so far found in Richmond consists of the use of a "blow-bottle" here illustrated. This is a bottle of suitable size to carry in one hand conveniently. A rubber atomizer bulb is attached and permits the operator to blow ammonia fumes from the bottle while holding the outlet nozzle near the suspected leak. This outfit can be easily manipulated with one hand.

Flexibility of Chlorinator Service

Chlorine control machines are relatively expensive, yet ample reserve against extra demands or repairs is absolutely essential in every plant. To reduce the number of machines needed, and yet leave reliable reserve at the Richmond plant has been installed a most successful transfer system. Three points of chlorine application before filtration and four control machines are available on the transfer. By means of the transfer system, the opening of a valve permits any or all of the four chlorinators to supply any or all of the three points of application. By changing hose connections two additional control machines may be substituted thus making six machines almost immediately available at any point of chlorine application. Thus six machines give as reliable service as would ordinarily necessitate nine machines.

The author wishes to gratefully acknowledge his indebtedness for the suggestions and criticisms of: M. C. Smith, Chairman of the A. W. W. A. Committee on Chemical Hazards in Water Works; L. H. Enslow, Research Engineer of the Chlorine Institute, and Editor of WATER WORKS AND SEWERAGE, and to Carl Liepold of Winnetka, Ill.

SOLVING CHLORINE ICE TROUBLE

By DON CALDERWOOD

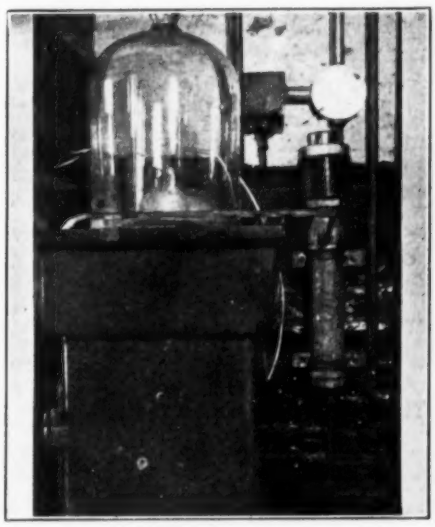
Engineer, Pennichuck Water Works Co.
Nashua, N. H.

IF you have had trouble with chlorine hydrate—usually called chlorine ice—forming in your chlorinator, you may be interested in hearing how we solved this problem.

A few years ago we purchased a Wallace & Tiernan type MCVM chlorinator. The following winter we experienced our first real trouble with so-called chlorine ice. We built a wooden box over the bell jar and put electric lights in it; we tried a unit from a sun bowl heater inside the standard under the tray; and then a combination of both. These gave results after a fashion but did not do a real workmanlike job—so after three or four seasons of makeshift operation we set out to find a permanent solution to the problem.

We purchased a 1,500 watt immersion heater with a three heat switch giving us 500, 1,000, or 1,500 watts as needed. We then took a piece of 2½ inch pipe about 10 inches long, screwed a cap on one end, a reducing coupling on the other, and into the reducing coupling we screwed the 1,500 watt heater. We next tapped into the cap and coupling for ⅛ inch copper tubing and after fastening the assembled unit to the chlorinator we disconnected the water supply line to the tray and with copper tubing made new connections so that all the water going into the tray first passed through the heating unit. To eliminate the possibility of forgetting to turn the heat either on or off, we purchased a pressure switch and connected it to the water supply line in such a way that it automatically turns the current for the heating unit on when we turn on the water supply to the chlorinator, and also turns it off when the water pressure is shut off.

This scheme worked perfectly for about three winters and then a ground started to show on our switchboard. We traced it to the heater and found that in our zeal for efficiency and in our desire to utilize all the heat available we installed the heater with the electric connections pointing down. During the humid summer weather condensation from the outside of the pipe had run down on the electric connections finally causing the ground. We have now reversed the unit, putting the heater in from the top and expect no more trouble. We find that low heat, or 500 watts, is all the current we need to use except for a few days during the coldest part of the winter.



Our First Heater

This heating unit worked so well that we decided to put one on the chlorinator in our other station even though we use that station very little in the cold weather. This chlorinator was an older model and did not have a separate valve and line for the tray water supply, so we connected the heater similar to the other installation but conveyed the warm weather from the heater directly over the top and into the tray. The water supply was adjusted so that the water flowing through the heater and into the tray was just a little less than the required amount, the remainder being supplied in the usual way through the float valve in the tray supply line.

WALLACE & TIERNAN CO., INC.

Manufacturers of Chlorine and Chemical Control Equipment

Newark 1, New Jersey

"THE ONLY SAFE WATER IS A STERILIZED WATER"

REPRESENTED IN

Albany	Chicago	Greensboro	Knoxville	Minneapolis	Salt Lake City
Atlanta	Cleveland	Houston	Lexington	Oklahoma City	San Francisco
Boston	Columbus	Indianapolis	Los Angeles	Philadelphia	Seattle
Bridgeport	Dallas	Jacksonville	Louisville	Pittsburgh	St. Louis
Buffalo	Denver	Kansas City	Lubbock	Portland, Ore.	Syracuse
Charlotte	Detroit			Roanoke	Washington, D. C.

Wallace & Tiernan Ltd., Toronto, Canada
Wallace & Tiernan Ltd., Winnipeg, Canada
Wallace & Tiernan Ltd., Montreal Canada
Wallace & Tiernan Ltd., London, England

FREE RESIDUAL CHLORINATION

Recent developments in water works practice show that bacteria practically cease to exist where Free Residual Chlorination, as accomplished by the Break-Point Process, is employed. Such chlorination assures the production of free available chlorine residuals which have a high killing potential. In many plants bacterial control by the Break-Point Process has been augmented with additional benefits such as improved coagulation, increased color removal, elimination of algal conditions, reduced chemical costs and increased length of filter runs with a resultant saving in wash water.

TYPE MASV AUTOMATIC SOLUTION FEED VISIBLE VACUUM CHLORINATOR

Where unusual or extreme fluctuations in water or sewage flow are encountered, the Type MASV meets the chlorination requirements. It embodies all the advantages of automatic proportioning of chlorine feed, and automatic starting and stopping with the outstanding features of the Visible Vacuum Control Chlorinator — rugged construction, simplicity of operation and low maintenance costs.

Type MASV Automatic Visible Vacuum Chlorinator

THE W&T HYPOCHLORINATOR

W&T Hypochlorinator

Chlorination of small water supplies involves problems which the W&T Hypochlorinator is especially designed to meet. This equipment feeds either calcium or sodium hypochloride in solution form and is furnished in three types.

The Electrically Operated type is particularly useful for small pumped water supplies. Since water pressure furnishes the major part of the operating power, the cost of electricity is but a few cents a day. Automatic Water Operated Hypochlorinators automatically proportion the chlorine solution to the flow of water and are especially adapted to small gravity water supplies with wide variations in flow.

The Belt Driven unit is a sturdy, dependable unit for use where electric power is not available or where operation is to be synchronized with pumping equipment driven by gasoline engine or other similar motive power.

Type MDPA Ammoniator

TYPE MDPA DIRECT FEED AMMONIATOR

A self-contained unit specially adapted to handling ammonia gas, embodying the same sound principles of design and construction exemplified in W&T Chlorinators. Rugged, accurate and dependable.

W&T Dry Chemical Feeder

DRY CHEMICAL FEEDERS

For the application of dry chemicals, Wallace & Tiernan offers a complete line of feeding equipment. The Types MO, MOF and MOI Dry Feeders include such advantages as positive agitation, easy calibration and accurate feed over ranges of from 0.5 to 200 pounds per hour, depending upon the chemical used.

CONVENIENCE

W&T is represented in each of the 35 cities listed above by chlorination specialists to assist in selecting proper equipment for any chlorination problem. Their recommendations involve no obligation.

Current literature on the many phases of chlorination, ammoniation and dry chemical feeding is available on request.

CONTEMPORARY CHLORINATION PRACTICES*

By HARRY A. FABER
Research Chemist, The Chlorine Institute, Inc., New York

WATER chlorination practice has evolved, during the past fifty years, from a relatively crude application to a highly efficient one. Such a steady process of progressive change is characteristic not only of this practice, but of all applications of scientific knowledge. The results of chlorination can be evaluated on the basis of the chemical and bacteriological results which have been accomplished by its use, and, for this purpose, it will be helpful to review briefly the history[1] of this method of water treatment.

Historical Summary

"Every decade," Dr. Max Thorek once said, "marks a distinct advance in science and art, reflecting the current history and progress of that particular period." The first decade (1896 to 1906) of chlorine's history as a method of water treatment witnessed the experimental use of chlorination and the inception of this method of treatment for continuous application. The earliest use of chlorine for water disinfection appears to have been by William M. Jewell in 1896, utilizing chlorine gas (produced electrolytically in small cells) in the experimental filtration studies conducted at Louisville, Ky. Three years later, at Adrian, Mich., Jewell again experimented with chlorine gas and then used chlorinated lime for temporary treatment of the effluent of full-scale filters. Chlorination of water, as a continuous treatment, was first adopted at Middlekerke, Belgium, where Dr. Maurice Duyk introduced the use of chlorinated lime in 1902, and where its use was continued until 1921. The second continuous use of chlorination was in England, where, in 1905, Sir Alexander Houston and Dr. McGowan started the application of sodium hypochlorite to disinfect the raw water supplying the Lincoln slow sand filters of the London system.

The second decade (1906 to 1916) was one of application. Following the first technically successful adoptions of chlorinated lime for water disinfection in North America—at the Bubbly Creek filtration plant of the Chicago stock yards and at the Boonton supply of Jersey City, N. J., in 1908—the application of this treatment grew rapidly. Midway through this period, the application of gaseous chlorine became practical, and, as improvements were made in chlorinating equipment, liquid chlorine steadily replaced chlorinated lime for the disinfection of water.

The third decade (1916 to 1926) was one of method. The chlorine demand of waters was found to be highly variable, and it came to be recognized that satisfactory chlorination could be obtained, not by a specific dosage, but by the residual which was provided. Ortho-tolidine had been proposed as an indicator for residual chlorine in 1909, and colorimetric standards for its use were developed in 1913. Its application as an important and practical control test for the chlorination of water supplies did not begin until 1918, but its use spread rapidly thereafter. Super-chlorination was studied in 1925, as a means of removing tastes and odors from water, and was put into operation the following year.

The fourth decade (1926 to 1936) was one of action. Chlorination became general practice for treatment of even the smallest water supplies. Chlorine-ammonia treatment, which was found to provide a more persistent residual than chlorine alone and to limit the development of many objectionable chlorinous tastes, was widely adopted.

The fifth decade (1936 to 1946) has been one of refinement. It has been distinguished by important studies of the fundamental factors which affect the action of chlorine in water and by the development of improved chlorination control measures. A new concept of chlorination practice has resulted from these refinements and has been put into practical application.

Reactions of Chlorine

In these five decades of development much has been learned and published concerning chlorine application and the process of chlorination employed. As might be expected, a loose terminology has come into use during this period. The serious need for clear definitions of terms has been recognized by a committee of the American Water Works Association,[1] and the following discussion is based largely on the terminology proposed by the committee.

Chlorine reacts with water to form hydrochloric acid and hypochlorous acid. The hypochlorous acid ionizes or dissociates into hydrogen ions and hypochlorite ions. Both reactions are dependent upon the pH value of the water, the first reaction predominating at low pH values and the second at high pH values:

$$Cl_2 + H_2O \rightarrow HCl + HOCl$$
$$HOCl \rightarrow H^+ + OCl^-$$

When chlorine is added to water, therefore, a portion of it may be present as molecular chlorine (Cl_2), as hypochlorous acid (HOCl) or as hypochlorite ion (OCl^-), and may be designated as *free available chlorine*.

The chemical activity of chlorine is a function of its capacity to combine with organic matter and to oxidize or supply oxygen to reducing substances. The intensity with which any oxidizing agent enters into chemical reaction is measured by its oxidation potential. Chemical reactions that occur when chlorine is added to water, and the rate at which they proceed, are dependent upon the oxidation potential of the free available chlorine.

When chlorine combines with other substances, its oxidation potential is reduced or may be completely neutralized. Chlorine reacts with ammonia to form chloramines and with other organic nitrogen compounds to form chloro-derivatives. With many forms of organic matter, particularly the hydrocarbons, chlorine addition products are formed. Those chlorine compounds lower in oxidation potential than free available chlorine may be designated as *combined available chlorine*.

Chlorine demand is defined as the difference between the amount of chlorine added to water and the amount of residual chlorine remaining at the end of a specified contact period. The chlorine demand expresses a definite equilibrium of the chemical reactions of chlorine in water under known conditions. For any water it will vary with the amount of chlorine applied, the time of contact and the temperature.

When a small dose of chlorine is added to water it combines with organic substances to form addition and substitution compounds. The residual remaining is predominantly combined residual chlorine. As larger amounts of chlorine are added to water, in order to obtain a higher residual, the chlorine demand will be increased and the residual remaining may include some free available chlorine.

When water receives a dose of chlorine sufficiently large to produce a definite residual in which free available chlorine predominates, the oxidation potential will be increased to such a degree that oxidation reactions will prevail. Instead of combining with organic substances, usually to form compounds having undesirable tastes and odors, the chlorine may oxidize these substances. Oxidation frequently will destroy such substances or change them to other and less complex compounds, with the resulting removal of disagreeable tastes and odors.

Chlorine Residuals

That chlorination can provide an effective safeguard against the transmission of water-borne diseases has been well established. During recent years, however, it has become increasingly evident that a false sense of security may result from the maintenance of chlorine residuals which are inadequate in quantity or quality. Suitable control measures must be used if the application of chlorine for disinfection and other purposes is to be successful.

For many years the control of chlorination has been accomplished by applying an amount of chlorine sufficient to produce a chlorine residual in the treated water. Only recently have practical methods been devised to differentiate, in the composition of a chlorine residual, between combined available chlorine and free available chlorine. Present methods enable the production of a chlorine residual of known composition by suitable control of the chlorination process. It should be recognized therefore, that the term, "a chlorine residual," is vague and no longer adequate.

The terms, "a combined available chlorine residual" and "a free available chlorine residual," are specific and constitute a new basis for distinguishing between various chlorination practices. All chlorination practices may be classified as one of these two types, whatever the point of chlorine application or the process of chlorination employed.

When a combined available chlorine residual is desired, the characteristics of the water will determine whether it can be produced by the application of chlorine alone, of the chlorine-ammonia process or of ammonia alone. If the water always contains sufficient free ammonia to maintain a combined available chlorine residual of the desired magnitude, then the application of chlorine alone will be required.

*From the *Jour. Am. W. W. Assn.*, Mar., 1947. Reprinted by permission of the Association.

If the water contains no ammonia, or too little to maintain a combined available chlorine residual of the desired magnitude, then chlorine-ammonia treatment is indicated. If the water contains free available chlorine and it is desired to convert this residual to combined available chlorine, then the application of ammonia will be necessary.

When a free available chlorine residual is desired, the characteristics of the water will determine whether it can be produced by applying chlorine alone, by the break-point process or by the super- and de-chlorination process. If the water contains no free ammonia, the application of chlorine alone will be required. If the water contains sufficient free ammonia to result in the formation of a combined available chlorine residual, then the break-point process or the super- and de-chlorination process will be required.

The efficiency of disinfection is a function of the composition of the chlorine residual, without regard to the chlorination process which is employed to produce it. The composition of the chlorine residual, therefore, provides the most suitable criterion for the classification of chlorination practices. On this basis, therefore, all modern practices should be identified either as "combined residual chlorination" or as "free residual chlorination."

Mechanism of Chlorination

Combined residual chlorination is defined as the application of chlorine to water to produce with the natural or added ammonia a combined available chlorine residual, and to maintain that residual through part or all of a water treatment plant or distribution system. A combined available chlorine residual should contain little or no free available chlorine and should not be confused with a false residual—that is, one due to ferric iron, manganic manganese or nitrites.

When water is chlorinated, the free available chlorine (which has a high oxidation potential) reacts rapidly with any oxidizable substances present. If the water contains natural or added ammonia, combined available chlorine (which has a low oxidation potential) is formed, and the rate of reaction with oxidizable substances is decreased. The low oxidation potential of combined available chlorine, compared with free available chlorine, accounts also for its slower bactericidal action. Data have been published to show that to obtain equivalent bactericidal action requires, with the same period of exposure, about 25 times as much combined available chlorine residual as free available chlorine residual; or, with the same amount of residual, a contact period about 100 times as long for the combined available chlorine residual as for the free available residual.

The chlorine-ammonia process is defined as the application of chlorine and ammonia to water, or of ammonia to water containing chlorine, to provide combined residual chlorination. Combined residual chlorination, produced by the chlorine-ammonia process, cannot be considered a satisfactory means for the disinfection of all water supplies or a corrective for all taste and odor problems; often it does not accomplish satisfactory results. Each problem must be studied separately to determine the efficiency of this process.

Free residual chlorination is defined as the application of chlorine to water to produce, directly or through the destruction of ammonia, a free available chlorine residual, and to maintain that residual through part or all of a water treatment plant or distribution system. A free available chlorine residual should contain little or no combined available chlorine and should not be confused with a false residual.

At low pH values, free available chlorine residuals are composed largely of hypochlorous acid (HOCl). Above pH 7.5, the hypochlorite ion (OCl^-) predominates; and, above pH 9.5, free available chlorine residuals consist almost entirely of hypochlorite ion. The bactericidal effect of hypochlorous acid is more rapid than that of the hypochlorite ion.

When free residual chlorination is employed for the pre-chlorination treatment of waters having a pH value below 9.5, it can solve many plant problems in addition to disinfecting the supply. With adequate contact time, this practice can be applied for the oxidation of ammonia, iron, manganese and protein substances in the water. Removal of the oxidized iron, manganese and some protein substances can be effected in part by coagulation and settling, and in part by filtration.

In general, the break-point process will be selected for free residual chlorination when a long contact period is available, and the super- and de-chlorination process will be selected when only a short contact period is available. All the chemical reactions of chlorine follow the law of mass action. Thus, the concentrations of chlorine and of oxidizable substances govern the rate and the completeness with which oxidation proceeds.

The *break-point process* is defined as the application of chlorine to water containing free ammonia to produce free residual chlorination. The amount of chlorine applied must be sufficient to provide, immediately or within the detention time available in the treatment plant, a free available chlorine residual that is at least 90 per cent of the composition specified.

The *super- and de-chlorination process* is defined as the application of chlorine to water to produce free residual chlorination in which the free available chlorine residual is so large that de-chlorination is required before the water is used. This process, as now defined, is a *controlled* chlorination practice. It may be employed, where no other chlorination process will accomplish the desired result, to attain the maximum rate of bactericidal action and of taste and odor reduction. De-chlorination can be accomplished by applying reducing agents, such as sulfur dioxide and its derivatives (sodium sulfite and sodium bisulfite), by using granular or powdered activated carbon and by submerged or spray aeration to volatilize a part of the residual chlorine.

Control of Chlorination

One of the most important contributions to the development of any science is the improvement in applied methods of measurement. This is especially true in the treatment of water with chlorine, because the results obtained by chlorination are not directly visible but must always be studied and measured indirectly.

The records show that Dr. Maurice Duyk[2] utilized starch-iodide titrations to control the first continuous application of chlorination in 1902. Earle B. Phelps,[3] in 1909, conceived the use of ortho-tolidine as a reagent for the detection of residual chlorine in water, and, in 1913, Ellms and Hauser[4] developed colorimetric standards to make this a quantitative determination. Only when Wolman and Enslow[5] demonstrated, in 1918, the suitability of the ortho-tolidine test for even the smallest supplies, however, did its application become widespread. This test met a definite need, enabling non-technical plant operators to regulate the addition of chlorine on the basis of a desired residual.

The ortho-tolidine test is simple and of sufficient accuracy, except for two limitations: it does not distinguish adequately between residual chlorine and certain interfering substances which may be present in the water; and it does not distinguish adequately between the forms in which residual chlorine may be present in the water. For thirty years, following the development of this test, many investigators have attempted to devise refinements of the ortho-tolidine test or to develop new tests employing other indicators.

With increasing contamination of water supplies, consumers frequently found chlorinated water to possess a chlorinous, chloro-phenolic or medicinal taste. In order to limit the production of objectionable tastes, the amount of chlorine applied was frequently reduced below the dose necessary for dependable disinfection; many water-borne epidemics have been traced to such undertreatment. The chlorine-ammonia process, the super- and de-chlorination process and the break-point process represent practices developed to meet the need for treatment methods that would provide a palatable water and still give a high degree of disinfection. Throughout this period the need for an improved method of residual chlorine determination became even more pronounced.

In 1944, F. J. Hallinan[6] proposed a simple modification of the standard ortho-tolidine test that employs only one additional reagent, a dilute solution of sodium arsenite, and enables the measurement of free available chlorine, combined available chlorine and interfering substances in water. Gilcreas and Hallinan[7] have studied the practical use of this test and report it fully applicable to plant and field conditions. The simple procedure of the ortho-tolidine-arsenite (OTA) test provides the best method at present avaliable for the control of chlorination. The "flash test" procedure using standard ortho-tolidine solution, developed by Laux[8] in 1940, has provided an extremely useful qualitative test for free available chlorine residuals. It is especially applicable as a plant control method, except when oxidized manganese is present in the water. These tests are included in the current edition of *Standard Methods*.[9]

The development of modern water chlorination practices and precise control methods is a tribute to many capable investigators. Their research has resulted in a clear understanding of the chemistry of chlorination. The new terminology proposed should materially assist better application of chlorination processes and more satisfactory interchange of information.

Contemporary Practices

The theoretical considerations of yesterday become the plant practices of today. Frequently, in fact, the practical application of chlorination has even preceded an understanding of the fundamental principles involved. During the last few years the technical literature has provided many ex-

amples of new or improved uses for chlorine that depend upon its bactericidal effects, its chemical effects or its utility for special purposes.

Bacterial Effects: To meet the current standards of water quality recommended by the U. S. Public Health Service and accepted by the American Water Works Association,[10] or to attain even higher standards of bacterial quality, Baylis[11] suggests the complete elimination of all lactose-fermenting organisms. Streeter,[12] as a result of extensive laboratory studies of chlorination practice, concludes that it is desirable to maintain a free available chlorine residual of at least 0.2 ppm. through the entire water distribution system.

In a survey of practices followed in several Indiana treatment plants, Adams[13] shows that lactose-fermenting organisms can be completely eliminated when the turbidity of finished water is below 0.3 ppm. and free available chlorine residuals are maintained. Wilson[14] has demonstrated at Fredericksburg, Va., that free residual chlorination can produce a finished water free from coliform organisms and also provide a stable residual which persists through an open reservoir far into the distribution system. Water free from lactose-fermenting organisms is also produced at Waterford, N. Y., where Yaxley[15] reports the addition of ammonia to finished water carrying a high residual of free available chlorine; while residuals ranging from 3.0 to 7.0 ppm. are maintained in the distribution system, there are no complaints of taste or odor in the hot or cold water.

Chlorination may have very useful applications to control the growth of bacteria even before water reaches the treatment plant. Jackson and Mayhan[16] show that free residual chlorination has eliminated growths of slime organisms which seriously decreased the carrying capacity of an important raw water supply line at Little Rock, Ark. Treatment of well waters in California by super- and de-chlorination, to remove hydrogen sulfide and control the growth of iron and sulfur bacteria, is reported by Alexander[17] to be very successful.

In a small water treatment plant at Beckley, W. Va., Chandler[18] has found free residual chlorination effective in reducing color, iron and manganese ahead of filtration. At Wheeling, W. Va., excessive pollution of a river supply makes the treatment problem very difficult, but Todd[19] reports that any concentration of phenols can be removed by chlorination and a free available residual provided.

In the distribution system, successful control of bacterial corrosion, by residuals of combined available chlorine and of free available chlorine, is described by Thomas.[20] Troubles due to iron bacteria have been corrected by Grove,[21] using combined residual chlorination. Griffin[22] reports that the growth of slime-forming organisms can be controlled by free residual chlorination.

Chemical Effects: The control of tastes and odors through the maintenance of free available chlorine residuals has been reported from many water treatment plants. At Houston, Tex., where chlorine is employed for this purpose and where ammonia is used to de-chlorinate the treated water partially, Harvill[23] notes that free chlorine residuals are more stable than combined chlorine residuals. The maintenance of a "chlorine blanket" throughout a reservoir at Baltimore, Md., is described by O'Brien[24] as accomplishing complete control of algae growths and accompanying turbidity.

Phillips,[25] at Durham, N. C., reports that the removal of manganese can be accomplished by the use of iron coagulants aided by free residual chlorination. The oxidation of iron and manganese at Olean, N. Y., is credited by Fuller[26] with resulting in marked lengthening of filter runs. At Ottumwa, Iowa, Poston[27] has developed an efficient technique using chlorine to remove mud balls from filters and to maintain filter sand in excellent condition.

Special Uses of Chlorine: Among many special uses, chlorine has been found effective for the sterilization of new and repaired water mains,[28] and for the emergency disinfection of mains and of water supplies.[29] It is used for the disinfection of deep wells[30] and is being employed more generally for restoring the capacity of wells.[31, 32] A relatively new method of treatment, the use of chlorine to prepare chlorine dioxide, is proving successful for a number of taste and odor control purposes.[33, 34]

Future of Chlorination

If the past may be used as a guide to the future, water chlorination practices will continue to develop into applications of increasing utility. It is already possible to witness the more general adaptation of photoelectric colorimeters and residual chlorine recording devices for greater precision in controlling the application of chlorine. It is to be hoped that chlorination continues to be influenced by developments in all fields of knowledge, until "every decade marks a distinct advance" in the future of this practice.

References

[1]Gilcreas, F. Wellington, Chamberlin, Noel S., and Faber, Harry A. "Chlorination and Other Disinfection Practices" a chapter in the *Manual of Water Quality and Treatment*. Am. Water Works Assn., New York (new edition in preparation).

[2]Whipple, G. C. Disinfection as a Means of Water Purification. *Proc. A.W.W.A.* (1906), p. 266.

[3]Phelps, E. G. *Testimony in re:* In Chancery of New Jersey: Jersey City *vs.* Jersey City Water Supply Co., Vol. 12, p. 6921 (decision rendered May, 1910).

[4]Ellms, J. W., and Hauser, S. J. Orthotolidine as a Reagent for the Colorimetric Estimation of Small Quantities of Free Chlorine. *J. Ind. Eng. Chem.*, 5: 915 (1913).

[5]Wolman, A., and Enslow, L. H. Chlorine Absorption and the Chlorination of Water. *J. Ind. Eng. Chem.*, 11: 209 (1919).

[6]Hallinan, F. J. Tests for Active Residual Chlorine and Chloramine in Water. *Jour. A.W.W.A.*, 36: 296 (1944).

[7]Gilcreas, F. W., and Hallinan, F. J. The Practical Use of the OTA Test for Residual Chlorine. *Jour. A.W.W.A.*, 36: 1343 (1944).

[8]Laux, P. C. Break-Point Chlorination at Anderson. *Jour. A.W.W.A.*, 32: 1027 (1940).

[9]*Standard Methods for the Examination of Water and Sewage.* Am. Public Health Assn. and Am. Water Works Assn., New York (9th ed., 1946).

[10]Anon. Drinking Water Standards—1946. *Jour. A.W.W.A.*, 38: 361 (1946).

[11]Baylis, J. R. The Modern Conception of the Bacterial Quality of Water. *J. Bact.* (July, 1940), p. 146.

[12]Streeter, H. W. Progress Report on Studies of Water Chlorination. *Jour. A.W.W.A.*, 35: 421 (1943).

[13]Adams, C. D. Chlorination Practices at Indiana Water Purification Plants. *Jour. A.W.W.A.*, 36: 1328 (1944).

[14]Wilson, Albert E., Jr. Bacteriological Results of Break-Point Chlorination. *W. W. & Sew.*, 89: 494 (1942).

[15]Yaxley, R. G. What's Your Chlorine Demand? *W. W. & Sew.*, 91: 90 (1944).

[16]Jackson, L. A., and Mayhan, W. A. Chlorine—A Critical Material Solves a Critical Problem. *W. W. & Sew.*, 90: 113 (1943).

[17]Alexander, L. J. Control of Iron and Sulfur Organisms by Super- and De-Chlorination. *Jour. A.W.W.A.*, 32: 1349 (1940).

[18]Chandler, E. E. First Year of Operation of Beckley's New Water Supply. *W. W. & Sew.*, 90: 158 (1943).

[19]Todd, A. R. Break-Point Chlorination at Wheeling, W. Va. *W. W. Eng.*, 94: 826 (1941).

[20]Thomas, Arba H. Role of Bacteria in Corrosion of Iron and Steel. *W. W. & Sew.*, 89: 367 (1942).

[21]Grove, Herbert S. Crenothrix Troubles Conquered. *W. W. Eng.*, 95: 357 (1942).

[22]Griffin, A. E. Microbiological Problems Related to Water. *Paper Tr. J.* (Aug. 28, 1941), p. 31.

[23]Harvill, Clyde R., Morgan, J. H., and Mauzy, H. L. Practical Application of Ammonia Induced Break-Point Chlorination. *Jour. A.W.W.A.*, 34: 275 (1942).

[24]O'Brien, G. L. Taste and Odor Control by Residual Chlorine Blanket. *W. W. Eng.*, 96: 996 (1943).

[25]Phillips, R. S. Experience with Manganese Removal at Durham, N. C. *W. W. & Sew.*, 90: 263 (1943).

[26]Fuller, N. M. Reforming the Olean Water Supply. *Am. City* (June, 1943), p. 67.

[27]Poston, H. W. Keeping Filters Clean with Clorine. *W. W. & Sew.*, 91: 209 (1944).

[28]Billings, C. H. Sterilization of New and Repaired Mains. *Jour. A.W.W.A.*, 34: 1777 (1942).

[29]Streeter, H. W. Emergency Disinfection of Public Water Supplies and Mains. *W. W. & Sew.* 89: 306 (1942).

[30]Jensen, Emil C. Disinfection Methods for Deep Wells. *Pub. Wks.* (Apr., 1942), p. 21.

[31]Brown, E. D. Restoring Well Capacity with Chlorine. *Jour. A.W.W.A.*, 34: 698 (1942).

[32]Huston, W. E. Recovering Well Capacity with Chlorine. *Jour. A.W.W.A.*, 38: 761 (1946).

[33]Synan, J., MacMahon, J. D., and Vincent, G. P. Chlorine Dioxide—A New Development in the Treatment of Potable Water. *J.N.E.W.W.A.*, 58: 264 (1944).

[34]Mounsey, R. J., & Hagar, M. C. Taste and Odor Control with Chlorine Dioxide. *Jour. A.W.W.A.*, 38: 1051 (1946).

OMEGA MACHINE COMPANY

(Division of Builders Iron Foundry)

91 Codding St., Providence 1, R. I.

REPRESENTATIVES

ATLANTA 3, GA.—W. D. Taulman & Associates, 452 Spring St., N.W.
BERKELEY 2, CAL.—Builders-Pacific, Inc., 921 University Ave.
CHICAGO 3, ILL.—Omega Machine Co., 1852 Peoples Gas Bldg.
CHARLOTTE 2, N. C.—Purser & London, Inc., Independence Bldg.
DETROIT 4, MICH.—W. A. DaLee, Inc., 9190 Roselawn Ave.
HUNTINGTON PARK, CAL.—Builders-Pacific, Inc., 2085 Belgrave Ave.
JACKSON, MISSISSIPPI—Feemster & Striger, 2903 North State St.
NEW YORK 7, N. Y.—Omega Machine Co., 20 Vesey St.
PHILADELPHIA 22, PA.—Wood & Preuit Engrg. Co., 1649 Broad St.
PITTSBURGH 22, PA.—Omega Machine Co., 1403 Oliver Bldg.
TORONTO, ONTARIO—Control & Metering, Ltd., 454 King St., West
WASHINGTON 5, D. C.—Wood & Preuit Engrg. Co., 1018 18th St., N.W.
ARGENTINA—Fiore Co., Avenida Passeo Colon 285, Buenos Aires.
BRAZIL—Oscar Taves & Co., Box 840, Rio de Janeiro.
COLOMBIA—W. A. Petersson, Consulting Engr., P.O. Box 1231, Bogota.
HAWAII—Alan Duvall, Box 33, Honolulu.
MEXICO—Dosificadores y Valvulas, SA% Dolores No. 16, Mexico City, D.F.
VENEZUELA—S.A., Eugene Capucio & Cia., Sociedad Tecnica y Comercial, Apartado Postal 1087, Caracas.

A COMPLETE LINE

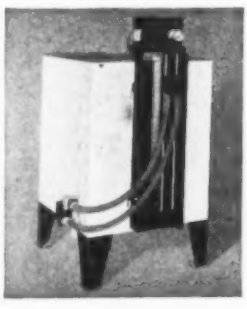
- Universal Feeders
- Lime Slakers
- Precision Solution Feeders
- Laboratory Stirrers
- Disc Feeders
- Gravimetric Feeders
- Rotodip Meter Feeders
- Rotolock Feeders
- Dust Removers and Filters
- Chemical Elevators
- Slow & Rapid Mechanical Mixing Equipment

GRAVIMETRIC FEEDER

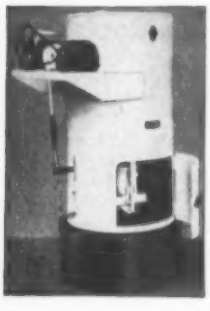
"Loss-In-Weight" Type

The most accurate type chemical feeder made. Indicates on the scale beam the weight of material in the hopper at all times. Feeds lump, granular or powdered materials at 100 different rates by increments of 1% of the maximum rate of feed, and records every pound of material fed. No calibration is required. The rate of feed is automatically controlled by the loss in weight in the hopper of material. The No. 1 Feeder shown at left feeds up to 2,000 lbs. per hour. Bulletin on request.

PRECISION FEEDER



Not an orifice feeder but a true Volumetric feeder, accurate within 1% for feeding solutions of Calgon, hypochlorite, copper sulphate, ammonium sulphate, etc., by gravity. Feeding range 100 to 1, from 1/25 to 200 gals. per hour, with standard tank sizes 25 to 200 gallons. Where electricity is not available, 8-day spring motors are used; meter-paced control is easily accomplished by flow proportional feeding. Bulletin on request.



UNIVERSAL FEEDER

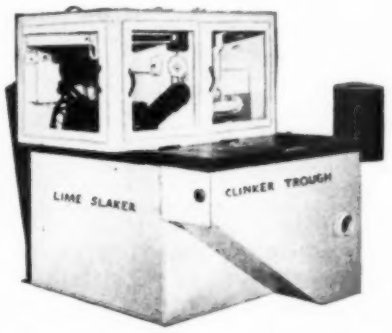
A rugged, dependable Volumetric feeder with oscillating throat at base of hopper. Easy micrometer screw adjustment gives a practical range of 40 to 1. Three sizes provide a feeding rate of 1 to 6,000 lbs. per hour. The feeder will successfully handle lime containing both lumps and fine powder; strings and trash will pass on through without clogging. Accuracy averages 3% although crushed lime may vary somewhat in weight per unit of volume. Send for Bulletin.

OMEGA LIME FEEDERS AND SLAKERS

Omega Continuous Lime Slakers are the product of years of specialization in the design and construction of equipment for Municipal Water and Sewage Plants. The majority of Omega Lime Slaker installations employ either the Belt Type or Loss-In-Weight Type Gravimetric Feeders. Slakers are available with capacities from 175 lbs. per hour to 10,000 lbs. per hour.

Outstanding features of the Omega Lime Slaker include:

- High speed mixing to promote rapid, thorough slaking.
- Efficient insulation and thermostatic heat control to maintain high slaking temperatures.
- Vapor removal devices to protect feeders from hot, moist vapors.
- Heat exchanger coils to preheat cold water for increased slaking efficiency.



OMEGA BELT TYPE GRAVIMETRIC FEEDER AND 500 LB./HR. OMEGA SLAKER

A feeder of extreme accuracy, weighing material continuously on a short conveyor belt carried on accurate sensitive scales. Can be set by a single dial to feed within 2% of the desired rate, and any departure from weight per unit of volume is automatically compensated. Alarms prevent over or under feeding; totalizer and recorder keep complete records of material fed. Automatic devices for feeding in proportion to variable flow are available. Bulletin on request.

ROTODIP FEEDER

For feeding from large supply tanks which may be located at a distance from the feeder. This cut-away view shows the metering wheel discharging into the receiving box at a high rate. Feeding range 1 to 800 gallons per hour. Variable speed drive gives an infinite number of speed changes from zero to maximum. Liquid feeders and dry feeders may be accurately synchronized to make up fixed strength solutions or suspensions.

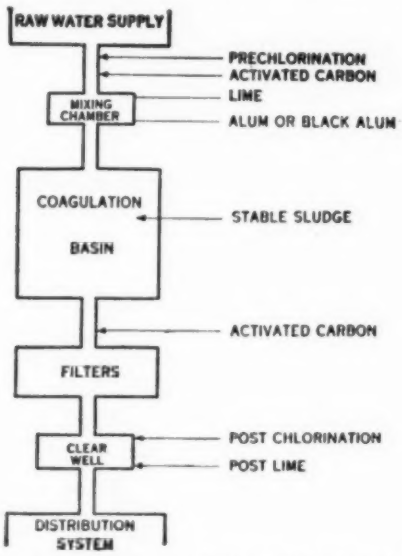
TASTE AND ODOR CONTROL WITH ACTIVATED CARBON

By E. A. SIGWORTH

Manager, Water Purification Dept., Industrial Chemical Sales Div., West Virginia Pulp and Paper Co., New York, N. Y.

ACTIVATED Carbon is a form of charcoal and, as used in water purification, is a very fine powder, or granular product. Since the finely powdered form is that most frequently used in water purification, the granular form will be eliminated from further consideration in this test.

Activated Carbon may resemble in appearance that of many other forms of carbon including charcoal, gas carbon black, etc. Therefore, it is not possible by a cursory examination to distinguish between an activated and an unactivated carbon. The true measure of an activated carbon is what it accomplishes in purification, and in the case of water purification this means its ability to remove odors and tastes. This removal is accomplished by concentration of impurities on the surfaces of the carbon particles. Thus an Activated Carbon may be considered as particles of carbon having a tremendous internal and external surface area which has been so purified as to eliminate any foreign materials clinging to the surface.



Flow Sheet for Chlorine and Activated Carbon Applications

Activated Carbons work by the physical phenomenon known as adsorption. By adsorption we mean the selective removal of materials from a solution, such as cloth picking up color from a solution when a dress is dyed. This should be distinguished from absorption such as is accomplished when water is soaked up by a sponge.

Methods of Application

Activated Carbon is usually applied continuously to a supply as the water passes through the purification system. In order to accomplish this, various proportioning devices of both dry and solution-type feeding have been employed successfully. Either solution or dry feeding equipment can be designed with sufficient accuracy to meet requirements in the water works field. The particular type of equipment to be employed for feeding depends upon the plant set-up, and individual preference. The dry feeding type of equipment is most frequently used because it involves less labor in feeding and control of the dosage. Many manufacturers have placed on the market feeding equipment specially designed for feeding activated carbon. It is suggested, however, that before purchase, the types of equipment be studied closely from the viewpoint of performance under all operating conditions.

Points of Application

Activated Carbon is insoluble and when added to water gives a black appearance. It is therefore evident that the carbon must be removed from the water before it enters the distribution system. Thus, carbon is usually applied ahead of sand filters. In normal water purification systems the points where carbon will logically be applied are; in the raw water, to the mixing basin, to the settling basin, or to the filters. Surveys have shown that the most common point of application for activated carbon is to the mixing basin, although each specific point of application has certain inherent advantages which must be taken into consideration in attempting to determine that point where best results will be accomplished. Furthermore, certain limitations may exist within individual plants preventing application at the point where best results might be expected.

First consideration must be given, therefore, to the specific design of the purification plant and a decision reached as to which points might be employed for the application. Factors which will play a part in such decisions are the degree of mixing of carbon with the water, and the mechanical design of the purification system. Carbon should not be applied where the water is in a relatively quiescent state since it will not disperse sufficiently to give contact throughout the entire body of water. Therefore, carbon should be applied at points where there is a restricted flow of water such as in mixing basins, near baffles in the settling basin, or to the filter influent.

Any point of application of carbon, whether before or after coagulation, has some advantages, and disadvantages. For example, where carbon is applied before coagulation, high dosages can be applied in order to take care of highly concentrated odors in a water supply. On the other hand, application of high dosages of carbon after coagulation might adversely affect the length of filter runs. Activated carbon when applied prior to coagulation partially settles out with the floc, resulting in a stabilizing action in the basins, thus decreasing the possibility of the water picking up odors due to decomposition within the water purification plant. Application of activated carbon to the filters is advantageous where odors have increased so suddenly as to get through the plant before they are noticed. Thus, application to the filters may save several hours of valuable time in controlling the odors. Furthermore, application in filters has been reported to be more economical because the odors at that point are less concentrated as a result of the effect of previous treatments.

There are so many inherent advantages to the various specific points of application that some operators have adopted the policy of applying carbon as a split treatment, part being applied to the water prior to coagulation and the remainder to the water after coagulation.

Effect of Other Chemicals

In any severe taste and odor problem it is advisable to consider the effect of other chemicals in order to determine the point of application of activated carbon which will accomplish maximum results. Because the effect of chemical treatment will vary quite appreciably within different plants, it is desirable that a study be made within the individual plant. Thus, any comments which we may make regarding the effect of other chemical treatments on odors must be considered as somewhat generalized statements. Aeration will normally accomplish an odor reduction of 10-15%, depending upon the efficiency of the aeration equipment and the concentration and type of odors. Coagulation appears to be a variable factor, since odors are sometimes increased and at other times are decreased. Actual experiences in plant operation are rather difficult to obtain because of the influence of activated carbon being utilized in the mixing basin. However, generally speaking it appears that coagulation does, in general, reduce odors to some slight extent, perhaps 5-10 percent. Filtration is also a rather questionable factor because of the influence of carbon within the treatment plant. As in the case of coagulation, the effect of filtration on odor is quite variable, reduction being very pronounced in some cases but slight in others. Perhaps a general all-around figure for the efficiency of filtration in reducing odors is approximately 10 percent. Thus the cumulative effect of various treatments of chemicals is relatively minor and cannot normally be considered as sufficient to correct a taste and odor condition in a water supply.

Dosages and Cost of Activated Carbon Treatment

Tastes and odors likely to be encountered in a water supply vary considerably. This can be readily understood when it is realized that tastes and odors may be caused by algae, decomposing vegetation, leaves, trade wastes, etc. In the case of algae alone, each of the many varieties frequently occurring in water supplies will give rise to odors peculiar to the specific type of algae.

Since these many odors are absorbed in different degrees by activated carbon, it is impossible to predict the dosage necessary. Furthermore, some odors are much more objectionable than others, even at extremely low concentrations. Cases have been reported where threshold odors as high as 30 have been considered palatable. Yet in one exceptional case many consumer complaints resulted from delivering water having a threshold odor of 2. In order to eliminate these complaints, it was eventually necessary to bring the threshhold odor on the delivered water to a value below 1.5.

Thus, in order to determine the carbon dosage, it is first necessary to determine the extent to which the odor must be removed in order to render the water palatable. Following this, the carbon dosage necessary to accomplish the desired removal can be determined by employing various amounts in laboratory or plant scale tests. The average dosage of carbon being applied for eliminating tastes and odors will usually range from 20-40 lbs. per million gallons. However, as explained above, this should be considered as only an average figure since lower or appreciably higher dosages may be necessary. To give some idea of the different dosages necessary, let us consider two specific cases. In one water plant in the Mid-West it has been found that with threshold odors of 100 it is necessary to apply approximately 800 lbs. of activated carbon per million gallons in order to deliver a palatable water. In another plant in the Eastern part of the United States, actual experience demonstrated that with a threshold odor of 80 in the raw water a carbon dosage of 25 lbs. per million gallons resulted in delivering a palatable water to the consumer.

The actual cost of treatment is, necessarily, a variable factor, depending upon the quantity of carbon necessary. However, it is desirable that costs of treatment should be calculated on an annual basis rather than on periodic intervals when a severe taste and odor epidemic may occur. If calculations are on an annual basis it will be realized that periods of high carbon dosages will be offset by those periods when extremely small proportions are necessary. Therefore, on an annual basis it has been estimated that the average cost of activated carbon for taste and odor control would represent only approximately 3c per capita per year. Certainly such a low cost for delivering palatable water should be no hardship on any community.

Applications to Reservoirs

Thus far, consideration has been given to the use of activated carbon where sand filters are available for removal of activated carbon and adsorbed impurities. Many water systems, throughout the country, having no sand filters, are occasionally faced with taste and odor problems and, in a number of cases, activated carbon has been applied directly to reservoirs.

Where carbon is applied to reservoirs, provision should be made for a sufficient settling period in order to eliminate any appreciable quantity of activated carbon entering the distribution system. Therefore, where possible the reservoir should be taken out of service for two or three days in order to allow the carbon particles to settle to the bottom. In some cases it has been impossible to take reservoirs out of service, even for short periods of time, and in such cases activated carbon has been applied, taking care that the application is not made too close to the outlet gate.

The dosage of carbon applied to reservoirs is usually kept rather low, utilizing from 10-20 lbs. of activated carbon per million gallons of water in the reservoir. If this dosage does not render the water palatable, further treatment can be made after a week or two. Utilizing successive treatments for a reservoir has many advantages. In the event any carbon does not get out into the distribution system small dosages will not be noticeable. Furthermore, from the labor point of view it is easier to handle the smaller amounts of carbon utilized in the stage treatments.

In applying activated carbon to a reservoir, it is desirable to wet the carbon thoroughly before application since carbon particles have a tendency to float upon the surface of the water. The recommended procedure is that followed by Marshall S. Wellington in treating the Beaver Brook Reservoir at New Haven, Connecticut. He has described the method employed as follows:

> "Two one inch holes were bored on opposite sides of a fifty gallon barrel near the bottom. Glass tubing with an inside diameter of an ordinary pencil was inserted in the rubber stoppers and the stoppers in their turn inserted in the holes in the barrel. Small stoppers were then inserted in the other ends of the pieces of glass tubing. The barrel was then placed on the stern of a boat. This allowed the outlet ends of the glass tubing to remain about four inches above the surface of the water. The man power was distributed as follows: One man to add the activated carbon to the barrel and to keep it agitated. The second man to row the boat. The third man in the bow of the boat with a hydrant pump to keep a supply of water from the lake going into the barrel. The outlets on the glass tubes were made the proper size so that the man could keep the barrel full and yet not be overworked.
>
> "The carbon was mixed in a heavy soupy mixture in the barrel at the start, and when the boat arrived at the place to start treatment the small stoppers were removed and the mixture allowed to run out. The man at the barrel added fresh carbon when the mixture became too thin, while the man with the pump kept the barrel full. The boat was rowed in a similar manner as when Copper Sulfate was applied. This method allowed the carbon to be added in a continuous manner at a very fast rate. A very noticeable feature of this method was the fact that the mixture flowing from the glass tubes penetrated under the surface of the water before it started to spread. After the addition of the carbon was completed there was very little floating on the surface of the water."

Application of activated carbon to a reservoir in sufficient quantity to control tastes and odors appears to have quite a lasting effect as evidenced by the fact that treatment is usually not necessary for a period of two or more years. This may be due to the film of carbon which has formed on the bottom of the reservoir. Experiences in water purification plants have demonstrated the stabilizing influence of activated carbon on sludge decomposition and it is quite possible that the carbon on the bottom of the reservoir is exerting a similar influence. There is also a possibility that the black carbon film may have some tendency to discourage certain types of algae growths.

Although the original cost for treatment of a reservoir with activated carbon may be considered somewhat high, the possible extended influence of the carbon for long periods of time should demonstrate definite economy for this method of carbon treatment.

Blackout of Algae

The first application of activated carbon for algae blackout is credited to William P. Bailey at the City Water Works, Council Bluffs, Iowa. Although the successful use of activated carbon for algae control in settling basins was discovered by Mr. Bailey many years ago, it has only been recently that other plants have adopted this application. At the Council Bluffs plant, activated carbon was applied, not only to control algae, but also to remove odors. The amount of activated carbon necessary for taste and odor control was ample to accomplish algae blackout, consequently the most economical carbon dosage necessary to accomplish this blackout was not determined. It remained for Hartung and Lischer, St. Louis County Water Dept., St. Louis, Missouri, to determine the dosage of carbon necessary to treat a particular area of settling basins. At the St. Louis County Water Company plant, it was found that algae could be controlled at a dosage of approximately ¼ lb. per thousand square feet of area. Records reported by Bailey on operations at Council Bluffs, Iowa, show that the average carbon dosage was 1.47 pounds per thousand square feet. It should be realized, however, that this latter dosage was utilized to accomplish taste and odor control as well as algae blackout.

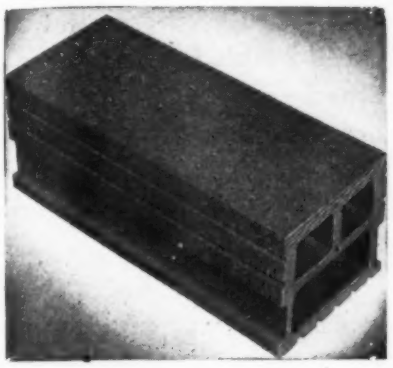
The method of application of activated carbon for algae control is somewhat similar to that recommended for reservoir application. The carbon is thoroughly wet and distributed over the surface of the basin once or twice a day. Since carbon is applied to exclude sunlight, it will be realized that application is not essential on cloudy days. Further details in the use of activated carbon for algae blackout are contained in a booklet entitled "TASTE AND ODOR CONTROL IN WATER PURIFICATION"*

*Gratis copies available from Industrial Chemical Sales Division, West Virginia Pulp & Paper Company, 230 Park Avenue, New York, N. Y.

F. B. LEOPOLD CO., INC.

2413 W. Carson Street **Pittsburgh 4, Pa.**

Water Purification and Sewage Plant Equipment



Standard Filter Block

GLAZED FIRE CLAY TILE FILTER BOTTOM

Permanent • Non-Corrosive • Economical

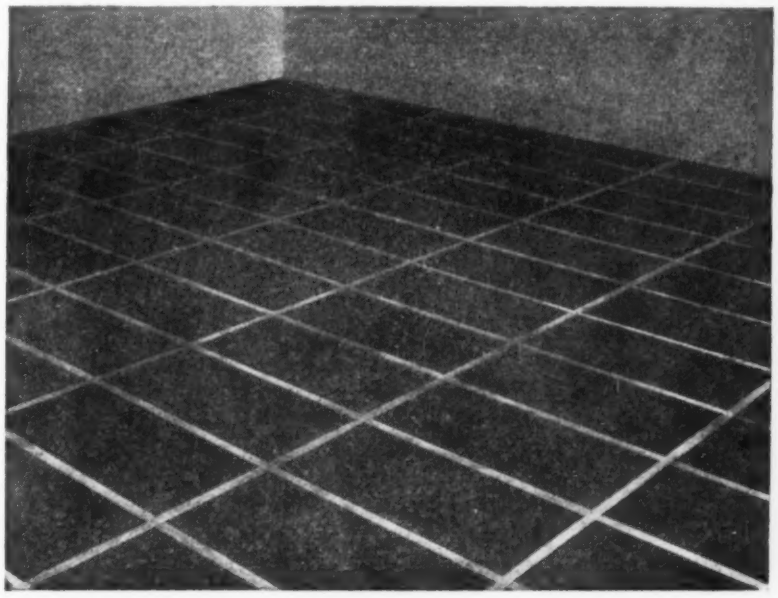
Designed to completely eliminate the many difficulties previously experienced with underdrain systems, the Leopold Duplex Filter Bottom has proven entirely successful in well over 100 municipal and private purification plants. Produced from de-aired fire clay—vitrified and salt-glazed, this unique filter bottom is impervious to attack by acid or alkali solutions, won't absorb any detrimental amount of water, and will last a lifetime.

The Leopold Filter Bottom is composed of separate blocks, each covering 2 square feet of filter floor and weighing approximately fifty pounds per square foot. These individual blocks are set level and firmly joined together, thus forming a strong bed that is not disturbed by wash water or air. The Leopold Duplex System assures a positive and equal collection of filtered water, reduces loss of head, and makes possible reduction of pipe and valve sizes.

Check These Features of The Leopold Filter Bottom

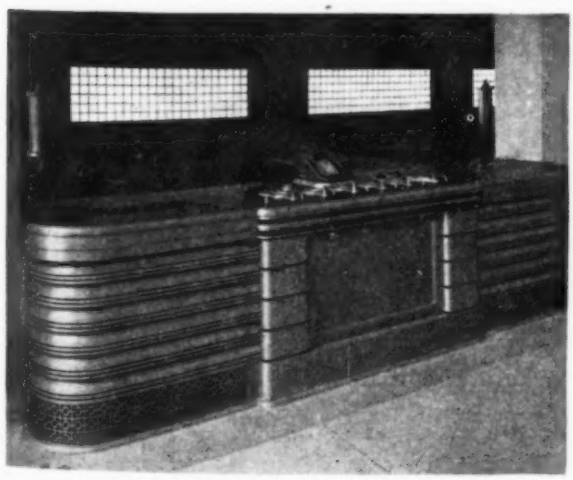
- Equal filtration over filter bed.
- Equal distribution of wash water.
- Blocks are combined into one heavy, strong unit.
- Vitrified, glazed fire clay blocks are practically non-absorbent.
- Glazed surfaces eliminate corrosion of blocks.
- Life of this filter bottom is extremely long.

View Showing Corner of Completed Filter



TYPE X-L DRY CHEMICAL FEEDERS

Where quality, accuracy and long life are desired, Leopold Chemical Feeders have long been the standard for feeding predetermined quantities of alum, lime, soda ash, carbon or other dry materials at a uniform rate. The machine is made in several sizes and capacities adjustable to suit a wide variety of operating requirements.



Filter Operating Table

The Leopold X-L Dry Chemical Feeder is compact, light in weight and durable, with all parts easily accessible. Simplicity in design keeps wear on parts at a minimum. Feeders are attractively finished with enamel paint.

FILTER OPERATING TABLES

Furnished in any size, combination or style desired, Leopold Operating Tables are master units for centralized control of hydraulic valves. They are designed to meet all requirements. The standard size tables are large enough for mounting any necessary gauges or samplers. All exposed metal parts can be furnished in any finish that may be desired.

In addition to hydraulic control tables, the F. B. Leopold Co. has available a complete line of equipment for filtration plants, including all types of cabinets, separate manifold headers, lubricated 4-way valves, operating plates and levers, and separate dial type valve opening indicators.

Literature and complete details available on request

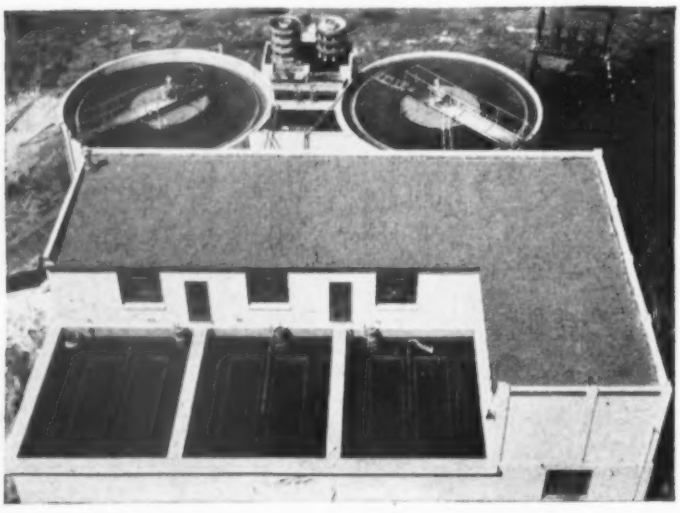
INFILCO WATER CONDITIONING

Trade-Mark*

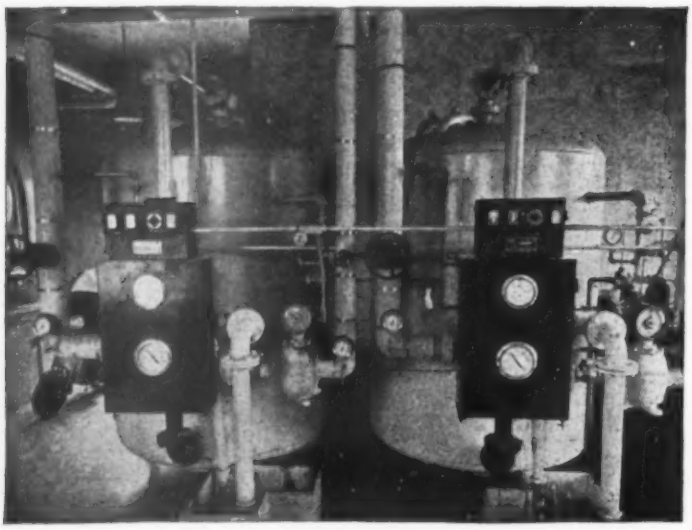
PRODUCTS

Accelators*
Aerators
Automatic Controls
Chemical Feeders
Clarifiers
Coagulators
Digesters
Dosing Siphons
Filter Equipment
Flow Controllers
Flow Gauges
Fluorex* Purifiers
Gravity Filters
Hydraulic Controls
Hydraulic Switches
Hydrodarco Purifiers
Level Controls
Lime Slakers
Loss of Head Gauges
Mixing Equipment
Pressure Filters
Proportioners
Recarbonators
Rotary Distributors
Samplers
Sewage Activators
Sewage Equipment
Sewage Griductors*
Stellar* Filters
Venturi Tubes
Wagner Underdrains
Water Filters
Water Softeners
Zeolites

"Everything from Accelators to Zeolites"



Accelator



Battery of Automatic Zeolite Softeners

STANDARDIZE ON INFILCO* PRODUCTS

Half a century of experience is back of the water conditioning and sewage treating equipment Infilco designs and builds for you. Take advantage of this. Standardize on Infilco products—everything from Accelators to Zeolites. Place undivided equipment responsibility squarely on the shoulders of Infilco. You'll get better results.

ACCELATORS

The Accelator for water softening, clarifying or stabilizing is one of the most important water conditioning developments in recent years. All treatment steps are combined and carried out rapidly in an incredibly small space. This resultant economy of space is reflected in reduced building requirements and costs.

In the Accelator operation, a body of slurry containing previously precipitated solids is recirculated thru mixing and reaction and return flow zones. Treating chemicals are added to the recirculating slurry as raw water is mixed into it. Chemical reactions reach equilibrium quickly and separation of the conditioned water from the surface of the slurry pool is rapid.

ZEOLITES—ION EXCHANGERS

Infilco Zeolites and other Ion Exchangers are available in a variety of types, each of which excels in some particular application or field of service. There are Sodium Exchangers for producing water of "zero hardness". There are carbonaceous and resinous Hydrogen Exchangers for reducing alkalinity and dissolved solids content. There are Anion Exchangers for the removal of fluorine and for demineralization of water.

Infilco Ion Exchanger Softeners, or Treating Plants, are of either pressure or gravity design, and, in sizes to meet any capacity requirement. Controls are furnished for manual, semi-automatic or fully automatic operation.

PRESSURE AND GRAVITY FILTERS

Clean, clear water is assured by the experienced engineering knowledge back of Infilco Pressure and Gravity Filtration Plants. Pressure filters are available in either standard types or new, space-saving Stellars. The Stellar operates on the principle of filtering through a bed of filter-aid formed rapidly over rigid elements. Pressure filters are built in many sizes and may be arranged in batteries of two or more for added capacity. Gravity filters are built to meet any capacity requirement.

**Trade-Mark Reg. U.S. Pat. Off.*

Consult INFILCO first in water and sewage treatment

AND SEWAGE TREATING EQUIPMENT

FILTER UNDERDRAINS

Wagner Filter Underdrains provide a primary distributing system of a manifold, or a false bottom waterway, with laterals on wide centers having orifices along the undersides, and a secondary distributing system of Wagner precast blocks fitting between the laterals. The system fills every requirement for perfect wash water distribution. If desired, these Underdrains can be furnished of entirely non-metallic materials—when made of Transite, they are practically everlasting.

TRANSFER SWITCHES, OPERATING TABLES, ROBOTROLS*

Infilco Transfer Switches provide fingertip control of hydraulically operated mechanisms. They have all the advantages of 4-way plugs or piston cocks—but none of their inherent disadvantages.

Infilco Operating Tables offer both utility and a pleasing appearance. They provide centralized and simplified control for hydraulically operated valves and at the same time furnish an attractive mounting for the control levers, indicators and gauges.

The Robotrol* is a robot operator for filters or softeners. It backwashes (or regenerates) a unit and then returns it to service—automatically, efficiently and without supervision.

CHEMICAL FEEDERS AND PROPORTIONERS

Infilco Dry or Solution Chemical Feeders provide means for volumetrically or gravimetrically measuring and feeding chemicals in any form. Capacities are from a fraction of a pound to hundreds of pounds per hour.

Infilco Continuous Lime Slakers combine in one continuous, automatic process, the consecutive operations of feeding and slaking quicklime, followed by the preparation and delivery of a milk of lime mixture suitable for water purification.

Infilco Proportioners maintain predetermined ratios between liquid flows or automatically vary the ratio of one flow with respect to another by electric, hydraulic or mechanical means.

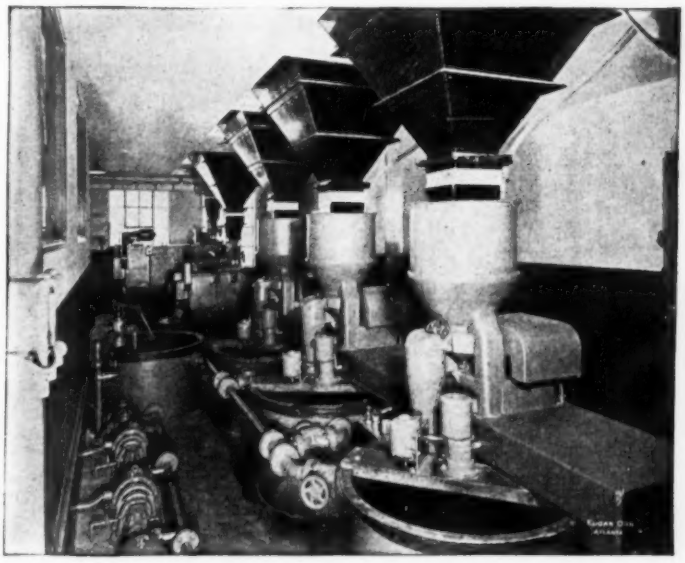
SWIMMING POOL RECIRCULATING SYSTEMS

Stellar Filter Recirculating Systems have the advantages of lower installation costs, material savings in chemicals and wash water. Stellar Filters are foolproof—cannot be injured by neglectful operation.

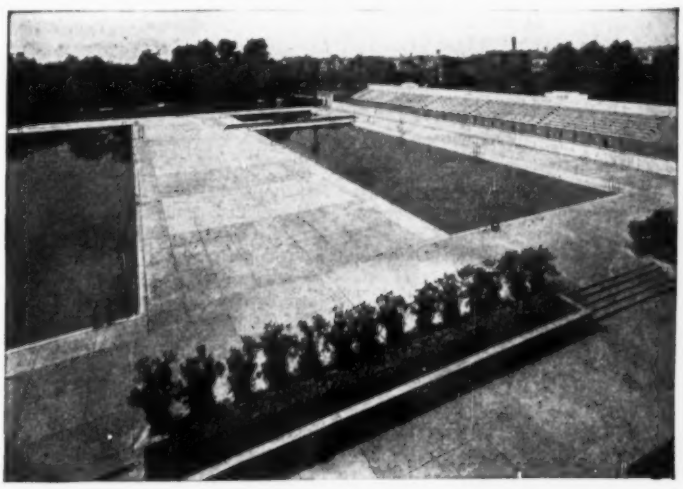
Conventional sand filter recirculating systems, both pressure and gravity, are also popular because of distinctive Infilco design features.

*Trade-Mark Reg. U.S. Pat. Off.

Installation of 68 Operating Tables in Gravity Filtration Plant



Battery of Dry Chemical Feeders and Lime Slakers and Feeders



Group of pools protected by an Infilco Recirculating System.

INFILCO INCORPORATED

325 W. 25th PLACE
CHICAGO 16, ILLINOIS

THE PERMUTIT COMPANY

World's Foremost Manufacturer of Water Conditioning Equipment

TELEPHONE LOngacre 3-4930 — 330 WEST 42nd St., N. Y. C. 18

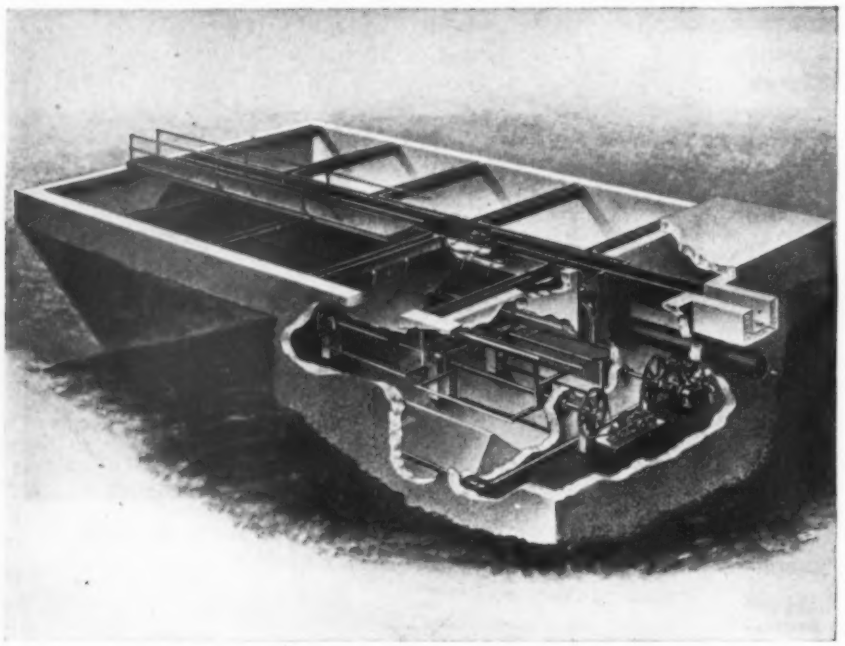
Cable Address: "PERMUTIT"

SALES OFFICES:

BOSTON 16, MASS., 700 Statler Bldg.
CHARLOTTE 3, N. C., 381 E. Morehead St.
CHATTANOOGA 2, TENN., 517 Hamilton Nat'l Bank Bldg.
CHICAGO 5, ILL., 407 So. Dearborn St.
CINCINNATI 8, OHIO, 3119 Griest St.
CLEVELAND 15, OHIO, 1836 Euclid Ave.
DALLAS 6, TEX., 5804 Anita St.
DAYTON 8, OHIO, 931 Patterson Rd.
DETROIT 26, MICH., 502 Free Press Bldg.
JACKSONVILLE 2, FLA., 131 E. Bay St.
KANSAS CITY 8, MO., 215 Pershing Rd.
LOS ANGELES 15, CALIF., 405 So. Hill Street
MINNEAPOLIS 2, MINN., 1111 Nicollet Avenue
PHILADELPHIA 3, PA., 34 South 17th St.
PITTSBURGH 12, PA., 615 Dollar Savings & Trust Bldg.
ST. LOUIS, MO., 3903 Olive St.
SYRACUSE 6, N. Y., 111 Rugby Road

PERMUTIT COMPANY OF CANADA, LTD.

Calgary, Alberta—Stanley Brock, Ltd., 523 8th Ave., West
Toronto, Ont.—S. A. McWilliams, Ltd., 60 Front Street, West
Winnipeg, Manitoba—Stanley Brock, Ltd., 145 Mkt. St., East
Montreal, Quebec—C. Kirkland McLeod, 1449 Crescent St.



FASTER, MORE ECONOMICAL COLD LIME TREATMENT

. . . WITH PERMUTIT'S NEW SPAULDING PRECIPITATOR

This revolutionary new equipment removes hardness and suspended solids in a much shorter detention period, saves chemicals, takes only half the space of old-type plants. The raw water and chemicals are mixed in a compartment where they are agitated with the suspended sludge from previously treated water. This speeds precipitation. The water and precipitates then pass into the filter upflow compartment which has a gradually increasing cross-section. The gradually reduced velocity of upflow supports the sludge filter at uniform density throughout the filtering zone. A rate of flow is reached at which the sludge is no longer supported, forming a clearly defined top to the sludge blanket. The effluent is clear, and for some purposes may not need further filtration.

Permutit makes every type and size of water conditioning equipment. Here are a few:

ZEOLITE WATER SOFTENERS

In Permutit's pressure zeolite softeners, a single multi-port valve, operated automatically or manually, conducts the raw water into a shell. The water is then evenly distributed through a bed of zeolite, and after collection flows to service completely softened. The valve also controls backwashing to clean the bed, regeneration with brine, and rinsing. Gravity zeolite units are also available.

PERMUTIT'S SPIRACTOR

The new cold lime soda water softener based on "catalytic precipitation" principle. Soft water in 8 minutes . . . no settling or voluminous sludge . . . Saves space and time.

PERMUTIT'S DEMINERALIZER

Produces a water practically free of all salts, at a fraction of the cost of distillation.

WATER FILTERS

Automatic and manual, gravity and pressure.

IRON REMOVAL FILTERS

FLOC FORMERS

SWIMMING POOL EQUIPMENT

WRITE FOR FREE BULLETINS:
THE PERMUTIT COMPANY, DEPT. G1
330 West 42nd St. New York 18, N. Y.

WATER CONDITIONING HEADQUARTERS

MODERN PRACTICES IN MUNICIPAL WATER SOFTENING

By S. B. APPLEBAUM, Pres.
Liquid Conditioning Corp., New York

MUNICIPAL water softening started in England about 60 years ago. The first municipal water softener in the United States of the lime-soda type was installed about 40 years ago, and the first municipal Zeolite water softener about 20 years ago.

Since that time the number of municipal water softening plants that have been installed in the United States has grown rapidly, as evidenced by Fig. 1.[1] This growth is caused by a greater realization of the benefits and savings which municipal water softening can provide, as well as the elimination of difficulties which the hardness of a water supply causes to the citizens of a community using it for household and industrial purposes. It is predicted that by 1950 there will be over 1,000 municipal water softening plants in the United States of both the lime-soda and the Zeolite type.

The hardness to which waters are softened in municipal plants is gradually being reduced. Not too many years ago it was considered good practice for a city to deliver a water of a hardness of up to 10 grains per gallon, or 171 ppm, as $CaCO_3$. Today municipal water softening plants are aiming at much lower figures, down to 3 to 5 grains per gallon, or 51 to 85 ppm.

W. D. Collins made a study of the municipal supplies in the United States of over 600 cities, and Table I[2] shows the population, in thousands and in per cent of the total, that was served with water of various amounts of hardness in 1932. Table II[2] gives the same information for Canada as studied by Leverin in 1938.

These tables indicate that the trend is towards a softer water for municipal application but that there is still opportunity for future installations of water softening plants where the hardness of the raw water exceeds about 120 ppm as $CaCO_3$.

Benefits from Municipal Water Softening

Soap Saving

W. H. Hudson made an interesting study comparing the cost of soap and other detergents in communities using hard water with their cost in communities using soft water. The hard water cities studied were Bloomington, Urbana and Chicago Heights, Illinois. These were compared with a soft water community, Superior, Wisconsin. Fig. 2[2] shows the annual cost of soap per capita, assuming soap at 16c per pound in these communities, plotted against the hardness.

The reason more soap is used in hard water communities is that the hardness reacts with the soap to form insoluble soap curds. These curds have no lathering effect and represent a wastage of soap by the hard water. The lather, which is desired when soap is used, can only be obtained after all of the hardness in the raw water has been consumed in making these curds. In this way the soap acts as a water softening chemical. When all of the hardness has been destroyed, additional soap used forms the lather.

Troubles Caused by Soap Curds

In addition to wasting soap, the curds formed are very objectionable. They are present as a milky-white precipitate in the water used in contact with the soap. This is apparent when taking a bath in hard water. Perfectly softened water in a bathtub stays clear, and the soap employed makes a luxuriant lather that floats on top.

Curds also form the well-known bathtub ring which is hard to clean and disagreeable in appearance. The curds also deposit on hair, skin, etc. That is why so many beauty parlors have installed small water softeners.

In the laundry, curds form deposits on linens, causing them to be yellowish in appearance and also rancid in odor. Soft water not only improves the appearance of the linens but prolongs their life by virtue of the fact that less bleaching is required.

Cleaning of dishes and glassware is difficult in hard water, and the contrast in appearance when using soft water is outstanding.

Saving in Plumbing Repairs

Hard water when used in hot water heaters causes a scale to form which plugs the coils of heaters and requires expensive plumbing repairs. This has been estimated by the Michigan State Department of Health[3] to average about $4 per family per year.

Effect of Hard Water in Cooking

Hard water toughens vegetables. Soft water makes for greater tenderness, better taste and improved color. It also improves the flavor of coffee and tea.

Fuel Loss

Hard water forms scale which wastes fuel. It has been estimated that this waste averages about $1.50 per person per year.

In the case of industrial plants, the scale caused by hard water in boilers not only causes fuel wastage but shutdowns of the boilers for cleaning and tube losses due to burning out of tubes. Consequently, most modern industrial boiler plants install water softeners to remove the residual hardness left in the treated water by municipal water softeners.

Methods for Municipal Water Softening

The two methods which have been used for municipal water softeners are: (a) Cold lime-soda ash process; (b) sodium Zeolite process.

Cold Lime-Soda Process

This method of reducing hardness was one of the first to be developed. It consists of adding lime (Clark process) to react with bicarbonate hardness, and adding soda ash (Porter process) to react with the sulfate and chloride hardness. The chemical reactions involved are as follows (underlined compounds are precipitated):

LIME REACTIONS

Calcium Removal

$$Ca(HCO_3)_2 + Ca(OH)_2 = \underline{2CaCO_3} + H_2O$$

Magnesium Removal

$$\underline{Mg(HCO_3)_2} + 2Ca(OH)_2 =$$

$$Mg(OH)_2 + \underline{2CaCO_3} + 2H_2O$$

Carbon Dioxide Removal

$$CO_2 + Ca(OH)_2 = \underline{CaCO_3} + H_2O$$

SODA ASH REACTIONS

Calcium Removal

$$Ca\begin{cases}Cl_2\\SO_4\end{cases} + Na_2CO_3 = \underline{CaCO_3} + \begin{cases}2\,NaCl\\Na_2SO_4\end{cases}$$

Magnesium Removal

$$Mg\begin{cases}Cl_2\\SO_4\end{cases} + Na_2CO_3 + Ca(OH)_2 =$$

$$\underline{Mg(OH)_2} + \underline{CaCO_3} + \begin{cases}2\,NaCl\\Na_2SO_4\end{cases}$$

TABLE I

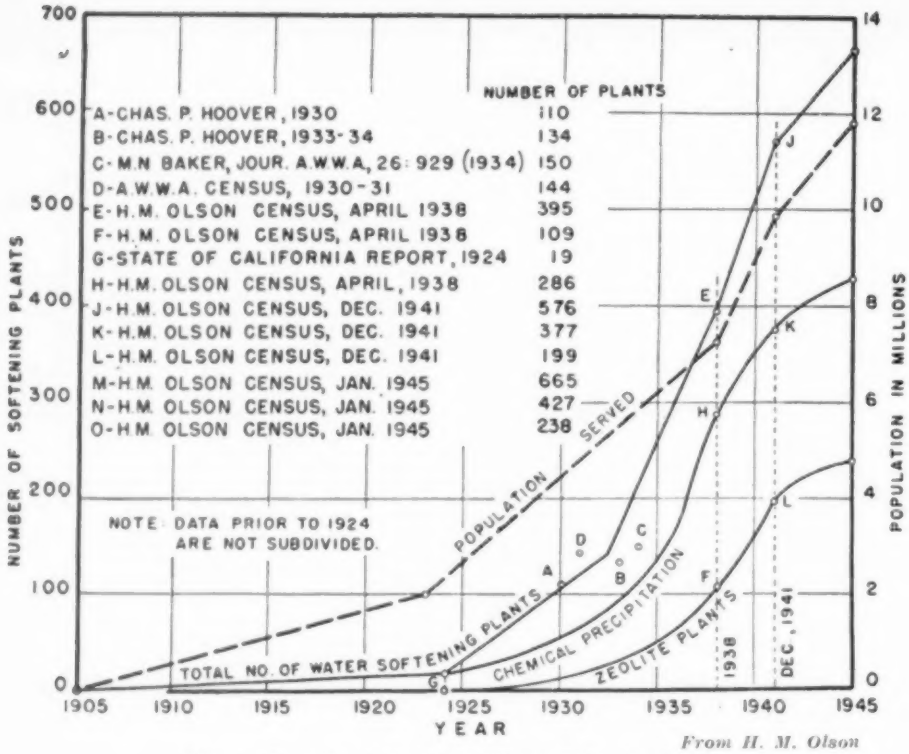
Varying Hardness and Population Served in U. S. in 1932

RANGE OF HARDNESS	POPULATION IN THOUSANDS	PER CENT OF TOTAL
parts per million		
1-60	20,372	29.5
61-120	18,536	26.9
121-180	10,579	15.3
More than 180	7,209	10.4
	56,696	82.1

TABLE II

Varying Hardness and Population Served in Canada in 1938

RANGE OF HARDNESS	POPULATION IN THOUSANDS	PER CENT OF TOTAL
parts per million		
1-60	907.9	16.3
61-120	1,458.7	26.2
121-180	1,057.2	19.0
181+	361.3	6.5
	3,785.1	68.0


NUMBER OF PLANTS
A-CHAS. P. HOOVER, 1930 110
B-CHAS. P. HOOVER, 1933-34 134
C-M.N BAKER, JOUR. A.W.W.A, 26: 929 (1934) 150
D-A.W.W.A. CENSUS, 1930-31 144
E-H.M. OLSON CENSUS, APRIL 1938 395
F-H.M. OLSON CENSUS, APRIL 1938 109
G-STATE OF CALIFORNIA REPORT, 1924 19
H-H.M. OLSON CENSUS, APRIL, 1938 286
J-H.M. OLSON CENSUS, DEC. 1941 576
K-H.M. OLSON CENSUS, DEC. 1941 377
L-H.M. OLSON CENSUS, DEC. 1941 199
M-H.M. OLSON CENSUS, JAN. 1945 665
N-H.M. OLSON CENSUS, JAN. 1945 427
O-H.M. OLSON CENSUS, JAN. 1945 238
NOTE: DATA PRIOR TO 1924 ARE NOT SUBDIVIDED.
POPULATION SERVED
TOTAL NO. OF WATER SOFTENING PLANTS
CHEMICAL PRECIPITATION
ZEOLITE PLANTS
1938
DEC., 1941
NUMBER OF SOFTENING PLANTS
POPULATION IN MILLIONS
YEAR

From H. M. Olson

Fig. 1. Growth of Municipal Water Softening Plants

Cold Lime-Soda Softeners

The early forms of cold lime-soda softeners were of the intermittent type, consisting of several batch tanks equipped with mechanically driven agitators. One of these tanks was filled at a time, dosed with lime and soda ash, agitated and then allowed to settle quiescently while one of the other tanks was being emptied through a decanter pipe. Filters followed the settling tanks. This intermittent type requires excessive space for the tanks and labor for operation of the various steps described.

The next form developed was the continuous type. The water flowed continuously into the settling tank, where it was mixed with a continuous and controlled stream of the lime and soda ash slurry, while settling of the precipitates took place at the same time. This saved labor of attention. The tanks had to be made large enough and properly baffled so that the velocities employed did not interfere with settling and so that there was a minimum of dead areas and channelling or short-circuiting areas.

The cold temperatures involved, however, interfered with rapid attainment of equilibrium. The precipitates formed were very finely divided and hard to settle. Reactions continued after the water left the settling tank; that is, the treated water was unstable. As a result some of the precipitates continued to form and deposit in the treated water lines and equipment. To stop these after-reactions, carbonation (addition of free CO_2 gas) or acid treatment was applied to the treated water to reduce the pH value by neutralizing the excess of reagent.

Sludge-Contact Reactor

The development of the sludge-contact reactor was a considerable step forward to render the cold lime-soda treated water more stable. The contact with large quantities of previously accumulated precipitates stimulated rapidity and completeness of reaction. This is the modern unit employed in cold lime-soda treatment today. It accomplished, in less than one hour, results equal or superior to those obtained with the old-fashioned continuous unit using four or more hours' retention. Chemicals are saved and a more stable water is produced. So stable is the treated water that some have called these sludge-contact reactors "stabilizers."

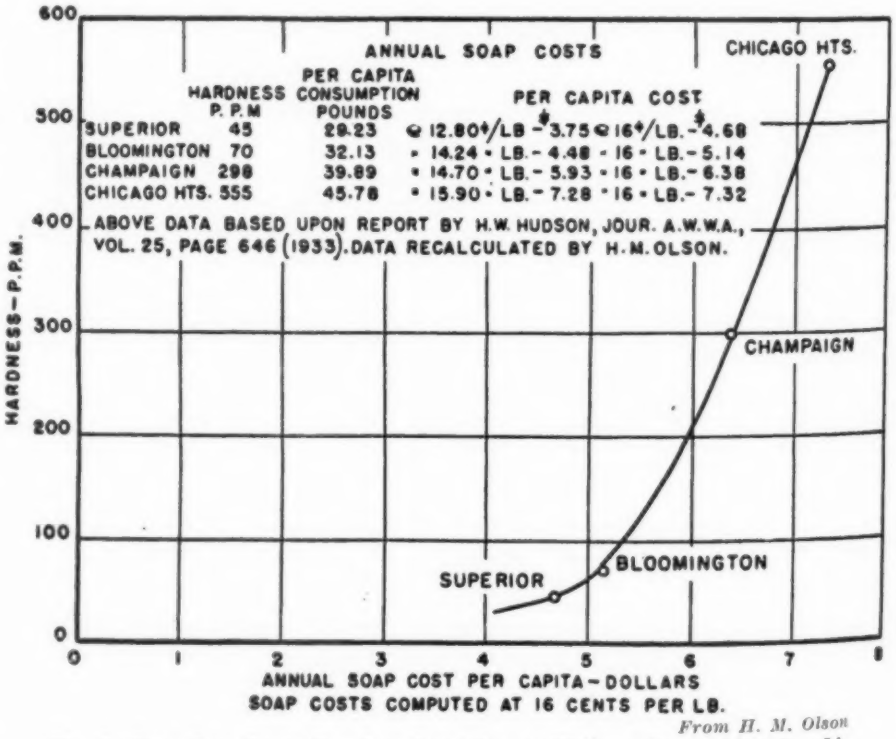
Before the sludge-contact softener was developed, sludge recirculation was practiced by which some of the settled sludge was pumped back to the inlet of the agitator or flocculation chamber. But this frequently resulted in imparting undesirable tastes and odors to the waters, especially in the summer when the settled sludge may have fermented.

The development of this type of reactor provided for sludge contact without allowing the sludge to settle. It thus avoided the repumping or recirculation of settled sludge, and also eliminated expensive sludge scraping, or collecting devices. Fig. 3 shows a typical sludge-contact reactor. It combines four functions:

(1) Proper agitation and mixing of chemicals and water; (2) sludge contact with a suspended deep sludge bed (blanket) of previously accumulated precipitates; (3) separation of the sludge from the water as the clear water emerges at the top of the unit; and (4) sludge concentration in internal concentration compartments in order to reduce the volume of sludge blowoff water discharged to waste.

The design *economizes* in space and in chemicals, producing better results in a fraction of the time required by the old-fashioned mixer and settling tank. It is used equally well for coagulation of turbid and colored waters, for softening of hard well waters by lime-soda, or for simultaneously softening and clarifying hard river waters. It is also efficient in absorption problems such as the removing of silica or fluorides by contact with magnesium compounds in the sludge.

In the design shown in Fig. 3, the precipitates formed by chemical addition are not allowed to settle out but are kept suspended by the slowly rotating agitator operating over the entire bottom of the tank. The water and chemicals enter the mixing zone near the bottom at the side where mixing is most efficient because of the relatively high tip speed of the agitator arm. The deflector baffle together with the deflecting blades induces the water to flow towards the central port, through which the sludge and water rise into the clarifying or sludge separating zone. The water then flows radially and outwardly towards the orifices of the peripheral collecting trough. The radially outward travel of the water takes place in the unrestricted clarifying zone at gradually decreasing velocities until a velocity is reached suffi-


ANNUAL SOAP COSTS
HARDNESS P. P. M
PER CAPITA CONSUMPTION POUNDS
PER CAPITA COST
SUPERIOR 45 29.23 @ 12.80¢/LB - $3.75 @ 16¢/LB. - $4.68
BLOOMINGTON 70 32.13 • 14.24 • LB. - 4.48 • 16 • LB. - 5.14
CHAMPAIGN 298 39.89 • 14.70 • LB. - 5.93 • 16 • LB. - 6.38
CHICAGO HTS. 555 45.78 • 15.90 • LB. - 7.28 • 16 • LB. - 7.32
ABOVE DATA BASED UPON REPORT BY H.W. HUDSON, JOUR. A.W.W.A., VOL. 25, PAGE 646 (1933). DATA RECALCULATED BY H.M. OLSON.
CHICAGO HTS.
CHAMPAIGN
BLOOMINGTON
SUPERIOR
HARDNESS - P.P.M.
ANNUAL SOAP COST PER CAPITA - DOLLARS
SOAP COSTS COMPUTED AT 16 CENTS PER LB.

From H. M. Olson

Fig. 2. Soap Cost Curve Based on Soap Cost at Uniform Basis of 16c Per Lb.

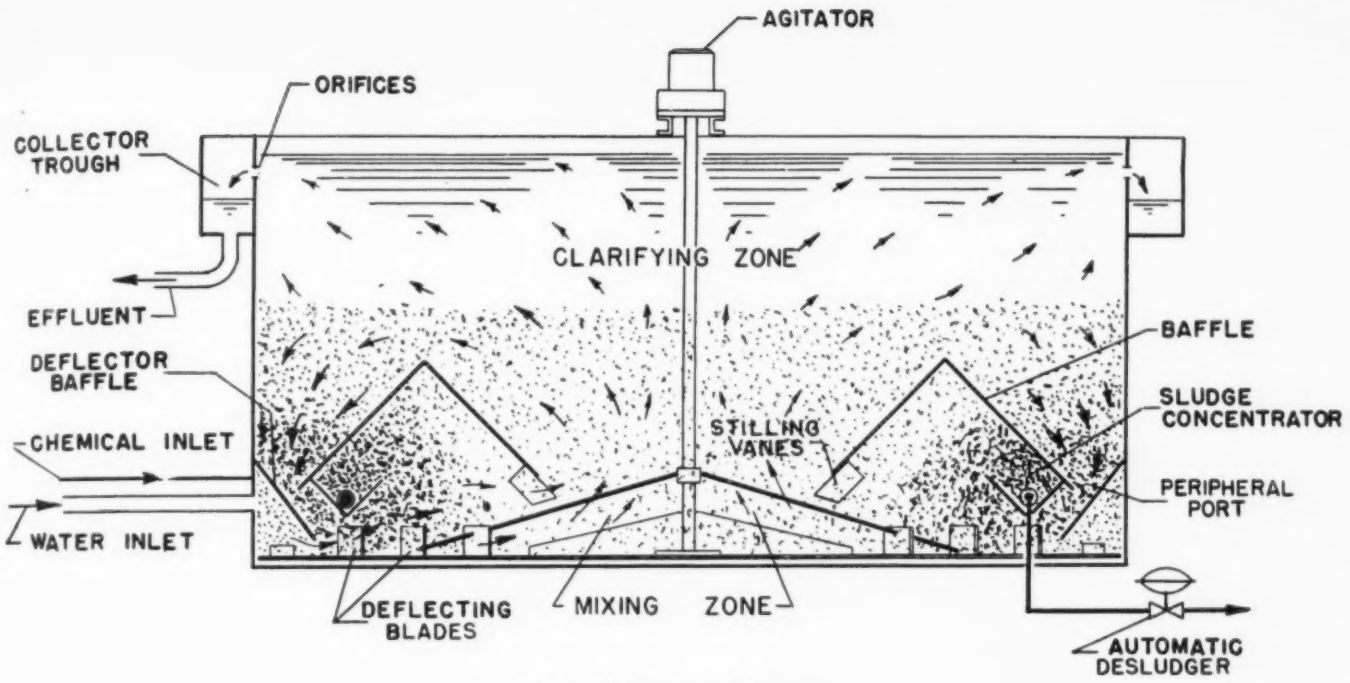


Fig. 3. Sludge Contact Reactor

ciently low to permit efficient separation of the water from the sludge.

Some of the water and sludge recirculate by returning through the peripheral port to the mixing zone. This recirculation ensures complete utilization of the chemicals. The top of the sludge is maintained above the inclined baffle separating the two zones.

Sludge-contact reactor units are built cylindrical in shape for economy of construction and the outer shell can be made of steel, wood or concrete.

Some of the sludge is collected in the sludge concentrator, where it is thickened or concentrated several times as compared with the strength of the suspended sludge bed (blanket). Automatic desludging devices blow off enough of this concentrated sludge to the sewer so that the top of the suspended sludge is kept at the optimum level for the best chemical results consistent with the clearest effluent.

The sludge-contact reactor has three outstanding features:

(1) Positive recirculation of sludge as the arrows indicate so that all of the chemical present is completely utilized and so that there are no dead areas in the tank.

(2) A large, slow-moving agitator operating over the entire bottom of the tank. This prevents any settling out and depositing of sludge on the floor of the tank. It avoids shutting down the reactor for cleaning such deposits or the use of separate sludge scraping devices for this purpose.

(3) Horizontal radial flow, as distinguished from upflow through a sludge blanket, permitting the use of smaller diameter tanks without the danger of sludge carry-over, because sludge particles separate more easily from a horizontal stream than from a vertically upflowing stream.

Sodium Zeolite Process

The sodium zeolite process is one of the most efficient methods of water softening. Essentially it comprises a container having a bed of the zeolite or sodium cation exchange material, supported on gravel or anthrafilt, below which is an efficient collection or underdrain system. As the water passes downward through the sodium zeolite, the calcium and magnesium cations in the water are exchanged for the sodium of the zeolite. When most of the available sodium has been exchanged so that the first trace of hardness appears in the effluent, the zeolite is backwashed and then regenerated or revivified by passing a solution of common salt through it. Sea water, if available, may be employed for regeneration. The excess brine is rinsed out and the unit is restored to service. A meter is provided to guide the operator in regenerating after a definite number of gallons of water has been softened, or to actuate automatic regeneration. The chemical reactions involved are as follows (the symbol Z represents the zeolite):

OPERATING REACTION

$$Na_2Z + \begin{Bmatrix} Ca \\ Mg \end{Bmatrix} \begin{Bmatrix} (HCO_3)_2 \\ Cl_2 \\ SO_4 \end{Bmatrix} = \begin{Bmatrix} Ca \\ Mg \end{Bmatrix} Z + \begin{Bmatrix} 2\ NaHCO_3 \\ 2\ NaCl \\ Na_2SO_4 \end{Bmatrix}$$

REGENERATING REACTION

$$\begin{Bmatrix} Ca \\ Mg \end{Bmatrix} Z + 2\ NaCl = Na_2Z + \begin{Bmatrix} Ca \\ Mg \end{Bmatrix} Cl_2$$

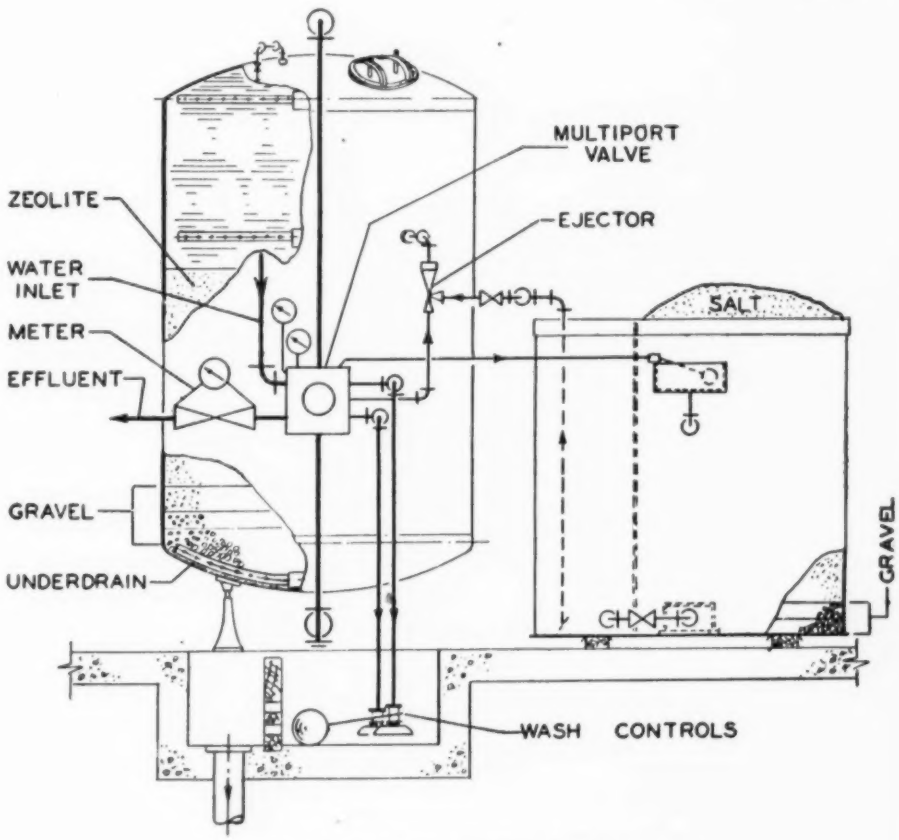


Fig. 4. Zeolite Softener with Multiport Valve

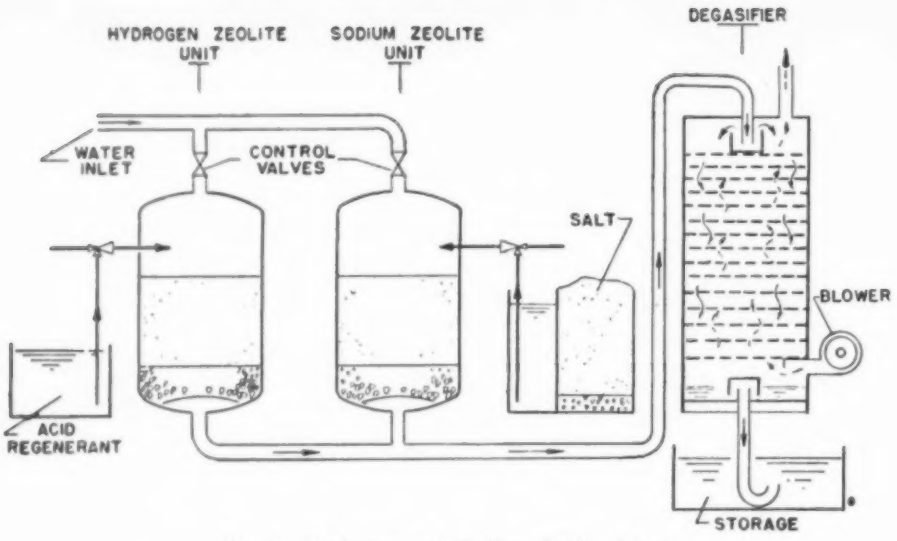


Fig. 5. Hydrogen and Sodium Zeolite Plant

Suitable multiport or individual gate valves are provided to control the operations. The regenerant solution is distributed inside the unit through a perforated pipe system to avoid channelling. Incoming hard water or outgoing dirty backwash water is likewise distributed or collected by a similar pipe system at the top. Fig. 4 shows a standard unit and salt tank with a multiport valve.

Several types of material are available for the sodium cation exchange material, such as glauconite, synthetic gel, and synthetic resin.

Resin, the most modern cation exchanger, is non-siliceous and therefore does not import silica to the treated water. Silica is objectionable for boiler feed purposes. Resin has a high capacity, several times as great as some of the old-fashioned zeolites, and permits higher flow rates per square foot of area.

The softened water produced contains practically no hardness—only 0 to 2 parts per million of hardness expressed as calcium carbonate (ppm. as $CaCO_3$) by the most rigid tests.

Since the usual municipal water softener is not intended to produce a treated water of lower hardness than 3 to 5 grains per gallon or 51 to 85 ppm. (expressed as $CaCO_3$), it is necessary to mix some of the hard unsoftened water with the effluent of the zeolite plant. This is done by bypassing some hard water around the zeolite plant and controlling the bypassed stream so that it is always in proportion to the softened stream. In that way the final mixed effluent will have a constant hardness at any particular figure desired.

If the raw water contains iron or other impurities, it may be necessary to remove these impurities by suitable equipment located on the bypassed pipe.

Comparison of Lime-Soda and Zeolite Methods

There are certain conditions which favor the lime-soda method, and other conditions which favor the zeolite method. A municipality, before deciding on which of these two methods to install in any given case, must compare the advantages and disadvantages of the two methods by making a thorough study of the investment and operating cost, space required, ease of operation, etc., before coming to the final decision.

Advantages of the Lime-Soda Method

(1) The use of lime for removing bicarbonate hardness is usually less expensive than the use of salt to regenerate sodium zeolite softeners. Therefore, if a water is high in bicarbonate hardness, the operating cost for lime treatment will be less than for zeolite.

(2) If the raw water is turbid and needs clarification in addition to softening, the lime-soda method is less expensive to install because it combines water softening and clarification. On the other hand, a clarification plant must be installed to precede the zeolite plant.

(3) If the raw water is polluted, the lime-soda method will aid in sterilizing the water, provided a sufficient time is allowed and the pH value is maintained high enough. The zeolite method does not sterilize the water and would require chlorination for the sterilization. Even in a case of lime-soda municipal water softener, reliance is not placed on the sterilizing effect of the high pH value alone, but in addition chlorinators are employed. The use of the sludge blanket type of lime-soda plant not only helps sterilization by virtue of the high pH value, but the sludge has coagulation and bacterial absorption effects.

Certain boards of health in the United States have required at least 4 hours in lime-soda plants to insure sterilization by the high pH value. This may be necessary for the old-fashioned settling tank where the sludge settles out, but with the modern sludge-contact reactor the bacterial absorptive power of the suspended sludge lessens the number of hours' retention required.

(4) The use of lime to remove bicarbonate hardness, as per the chemical reactions given above, precipitates this hardness, removing it from the water without substituting any other salts in its place. The alkalinity of the original water is, therefore, reduced by the amount of bicarbonate hardness eliminated. This reduction in alkalinity is not accomplished by the sodium zeolite process, because in that process sodium bicarbonate in the soft water is substituted for the calcium and magnesium bicarbonates present in the raw water. The alkalinity in the zeolite treated water is the same as in the raw water.

If the alkalinity of the water is high, its reduction is desirable for many purposes, particularly industrial application, such as for textile plants and boiler plants, etc.

Advantages of the Zeolite Process

(1) The zeolite process can be carried out under pressure by passing the water from the raw water pump directly through a pressure zeolite softener to service. This avoids repumping. Repumping is usually necessary with lime-soda plants.

(2) The space required by the zeolite plant is usually much less than for lime-soda.

(3) If the water is high in non-carbonate hardness, the cost of the salt to regenerate the zeolite is usually less than the cost of soda ash in the lime-soda process. For this reason, in some cases, a combination of lime pretreatment followed by zeolite has been used. This was true of the latest large municipal water softening plant installed near Los Angeles, California.

(4) The handling of salt, dissolving it in a saturated brine in underground wet salt storage basins, is much less troublesome than the storage of lime and soda ash and their handling.

(5) The lime-soda process produces precipitates which have to be settled out and finally disposed of. If there is a very large river alongside, the precipitates or sludge may be discharged into this river without difficulty. Usually, however, objections arise even in the case of fairly large rivers,

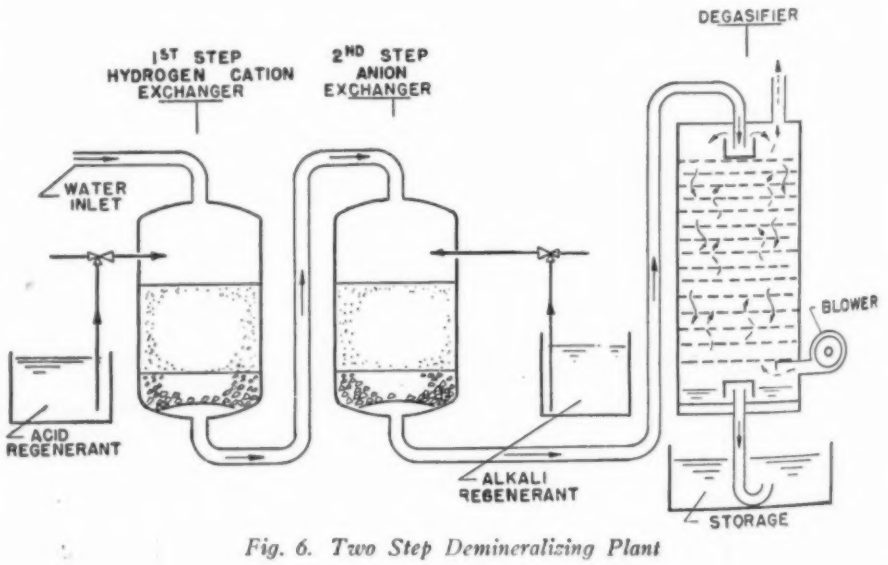


Fig. 6. Two Step Demineralizing Plant

because the sludge settles out to the bottom of the river and, later, during a rainy season, high velocities in the river stir up the settled sludge and carry it downstream, where it may cause complaints from users of the river. In many cases there is no good sized river to receive sludge. The practice then is to collect the sludge in lagoons where it is allowed to dry out in the sun and it is then hauled away. This is a very troublesome operation and it is unsightly. Some work has been done in the last few years to dry the sludge and calcine it to make lime out of it again. This involves keeping the magnesium precipitates separate from the calcium precipitates. It also involves a considerable investment in the lime reclamation equipment. Furthermore, an excess of lime is produced by this reclamation, which has to be disposed of by sale to others.

The zeolite process is free from these difficulties because no precipitates are formed and the waste liquors, during regeneration, contain calcium and magnesium chlorides which are very soluble and flow readily into the sewer system.

(6) The zeolite softeners are usually easier to operate, requiring less skill in their handling than lime-soda softeners.

(7) The zeolite process does not add any objectionable excess of reagent to the water, which may occur with the lime-soda softener if there is any negligence in handling of the lime-soda softener. In the case of lime-soda, too much lime, or too much soda-ash, may render the water too high in pH value.

(8) The zeolite treated water is stable and does not tend to after-react. The lime-soda treated effluent is not *completely* stable even after the use of sludge-contact reactors and carbonation or other means of reducing the pH value, which are frequently employed after the lime-soda plant to increase the stability of the treated water.

(9) The zeolite plant, when operated under pressure, handling a well water free from dissolved oxygen, can produce a noncorrosive effluent because there will be no dissolved oxygen in the treated effluent. This assumes that there will be no exposure of the treated water to the atmosphere.

Where oxygen is picked up, however, or where the raw water contains oxygen, the zeolite treated water may not be noncorrosive, and alkali such as sodium silicate or soda-ash may have to be added to raise the pH value so that there will be a tendency for a slight precipitation to occur in the city distribution system. This precipitation provides a protective film on the inside of the pipe to prevent corrosion due to dissolved oxygen and carbon dioxide. The lime-soda process, as stated previously, provides a treated water of high pH value, which tends to after-react and form deposits in the distribution system. It is, therefore, less likely to cause corrosion and, in fact, the excessive pH value present must be reduced to control the amount of such after deposits formed.

Future Developments

In addition to sodium zeolite there are now available two other methods, namely hydrogen zeolite and demineralizing. These have not yet been applied for municipal purposes, but they have made great progress in the industrial field. The time is undoubtedly approaching when they will receive application for the removal of hardness as well as other dissolved impurities. The hydrogen zeolite is regenerated with acid instead of salt. It removes alkalinity as well as hardness. It, therefore, removes the objection to sodium zeolite previously mentioned. It will find application where acid is cheap and where lime may not be so cheap. It will particularly be preferred where the problem of sludge disposal with the lime-soda plant would be insuperable, and yet where it is desired that the alkalinity be reduced. Fig. 5 shows a typical hydrogen and sodium zeolite plant.

Demineralizing is a two-step process. The water first passes through a hydrogen zeolite unit and then passes through an anion exchange unit. The first unit transforms all the salts into their corresponding acids. The second unit absorbs these acids and produces a water practically free from electrolytes. Fig. 6 shows a typical demineralizing plant. In that respect it is the equivalent of distilled water. For highly mineralized raw waters, demineralizing may find application in the future, not to produce distilled water, which is not needed for municipal practice, but to reduce the sulfates and chlorides to a partial extent and thereby improve a raw water for irrigation and other similar purposes. Sulfates and chlorides are not removable by either the lime-soda or the zeolite processes.

As the demand for higher quality of treated water rises, these newer processes of hydrogen zeolite and demineralizing will, undoubtedly, take their place in municipal water treatment practices.

References

1. H. M. Olson. Census of Municipal Water Softening Plants. *J.A.W.W.A.*, 37, June, 1945.
2. H. M. Olson. Benefits and Savings from Softened Water for Municipal Supply. *J.A.W.W.A.*, 31, 607 (1939).
3. Michigan State Board of Health, Bulletin 15.

FLOW OF WATER IN HOUSE SERVICE PIPES

(To find the discharge in gallons, multiply by 7.48)

Condition of Discharge	Pressure in Main Pounds per Square Inch	Discharge in Cubic Feet per Minute from the Pipe								
		Nominal Diameters of Iron or Lead Service Pipe in Inches								
		½	⅝	¾	1	1½	2	3	4	6
Through 35 ft. of service pipe; no back-pressure.	30	1.10	1.92	3.01	6.13	16.58	33.34	88.16	173.85	444.63
	40	1.27	2.22	3.48	7.08	19.14	38.50	101.80	200.75	513.42
	50	1.42	2.48	3.89	7.92	21.40	43.04	113.82	224.44	574.02
	60	1.56	2.71	4.26	8.67	23.44	47.15	124.68	245.87	628.81
	75	1.74	3.03	4.77	9.70	26.21	52.71	139.39	274.89	702.03
	100	2.01	3.50	5.50	11.20	30.27	60.87	160.96	317.41	811.79
	130	2.29	3.99	6.28	12.77	34.51	69.40	183.52	361.91	925.58
Through 100 ft. of service pipe; no back-pressure.	30	0.66	1.16	1.84	3.78	10.40	21.30	58.19	118.13	317.23
	40	0.77	1.34	2.12	4.36	12.01	24.59	67.19	136.41	366.30
	50	0.86	1.50	2.37	4.88	13.43	27.50	75.13	152.51	409.54
	60	0.94	1.65	2.60	5.34	14.71	30.12	82.30	167.06	448.63
	75	1.05	1.84	2.91	5.97	16.45	33.68	92.01	186.78	501.58
	100	1.22	2.13	3.36	6.90	18.99	38.89	106.24	215.68	579.18
	130	1.39	2.42	3.83	7.86	21.66	44.34	121.14	245.91	660.36
Through 100 ft. of service pipe and 15-ft. vertical rise.	30	0.55	0.96	1.52	3.11	8.57	17.55	47.90	97.17	260.56
	40	0.66	1.15	1.81	3.72	10.24	20.95	57.20	116.01	311.09
	50	0.75	1.31	2.06	4.24	11.67	23.87	65.18	132.20	354.49
	60	0.83	1.45	2.29	4.70	12.94	26.48	72.28	146.61	393.13
	75	0.94	1.64	2.59	5.32	14.64	29.96	81.79	165.90	444.85
	100	1.10	1.92	3.02	6.21	17.10	35.00	95.55	193.82	519.72
	130	1.26	2.20	3.48	7.14	19.66	40.23	109.82	222.75	597.31
Through 100 ft. of service pipe and 30-ft. vertical rise.	30	0.44	0.77	1.22	2.50	6.80	14.11	38.63	78.54	211.54
	40	0.55	0.97	1.53	3.15	8.68	17.79	48.68	98.98	266.59
	50	0.65	1.14	1.79	3.69	10.16	20.82	56.98	115.87	312.08
	60	0.73	1.28	2.02	4.15	11.45	23.47	64.22	130.59	351.73
	75	0.84	1.47	2.32	4.77	13.15	26.95	73.76	149.99	403.98
	100	1.00	1.74	2.75	5.65	15.58	31.93	87.38	177.67	478.55
	130	1.15	2.02	3.19	6.55	18.07	37.02	101.33	206.04	554.96

From the Handbook of the Buffalo Tank Corp.

THE ANTHRACITE EQUIPMENT CORP.

Anthracite Institute Building
WILKES-BARRE, PENNA.

ANTHRAFILT — an Improved Filter Medium

Trade Mark Reg. U. S. Pat. Off.

Address sales and technical inquiries to

Palmer Filter Equipment Company, 822 E. 8th St., Erie, Penna.

Anthrafilt and Its Application

Anthrafilt is made from a **selected** Pennsylvania anthracite which has been cleaned so as to have a minimum ash. This cleaned anthracite is then screened and classified hydraulically to yield sizes suitable for filter purposes.

Anthrafilt is used as a mechanical aggregate in place of sand and gravel in all kinds of filters, i.e.

Rapid gravity filters	Slow filters
Swimming pool filters	Pressure filters
Hot process softening filters	Oil removal filters
Cold process softening filters	Alkali filters
Mechanical sewage filters	Acid filters
Revolving screen filters	Sewage sludge-beds
Portable filters	Household filters

The entire filter bed may be made up of Anthrafilt of various sizes or only the top layer may be of Anthrafilt over the usual bed of gravel.

Advantages of Anthrafilt

High Filtration Rate: Rates up to 200 mgad are obtainable with Anthrafilt without sacrifice of effluent quality. The accepted average rate with sand is 125 mgad.

Long Filter Runs: The larger, irregular Anthrafilt grains allow less clogging with algae or other fibrous substances. The angular grain surfaces provide greater entrapping areas for the removal of turbidity and bacteria. The differences in shape and specific gravity of the grains, by decreasing classification after back washing, allow the whole depth of the filter bed to be active in the filter operation.

Low Wash Water Costs: The long filter runs and consequent less frequent washing and the low degree of packing after back washing combine to cut the usual wash water requirements at least in half.

No Cementing with Lime, Manganese or Iron: Lime will coat on Anthrafilt but this coating readily flakes off without any cementing action if filters are properly operated. Manganese and iron salts precipitated on Anthrafilt by the lime treatment are easily removed by back washing.

High Degree of Expansion: 50% expansion is obtained with half the back wash velocity required for sand.

Coarse Sizes Can Be Used: The irregular shape and natural filtration characteristics permit the use of much larger sizes with equal results.

Gravel Beds Stay Flat: No ridging or mounding and less cracking and pulling away from side walls during operation.

Low First Cost: Lighter weight per unit volume balances the cost differential between Anthracite and sand and saves on freight and handling charges.

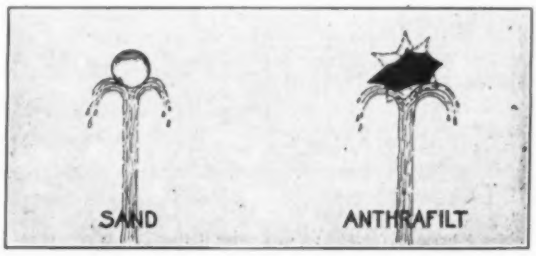
Filtration Characteristics

Anthracite granules are irregular shaped and of varying densities. Weights run about 53 pounds per cubic foot as against 100 pounds for sand. The irregular shapes provide greater porosity resulting in more rapid filtration with no loss in character of effluent and with considerably less loss of head.

The variable densities of Anthrafilt particles cause less classification after back washing and the lighter, irregular shapes allow easier expansion and more effective cleaning.

The greater bulk of Anthrafilt requires less tonnage per filter bed. Attrition losses amount to less than 0.25% per year.

Anthrafilt successfully removes lime, iron and manganese salts and will not form a permanent coating under proper conditions of treatment and filter operation. Lime flakes off easily without cementing and the iron and manganese salts are readily removed by back washing. Oil is easily removed from boiler water after coagulation with ferric sulphate, ferrous sulphate or alum. Anthrafilt can also be used for the filtration of acetic and sulphuric acids and caustic soda solutions. Being insoluble in alkaline waters, Anthrafilt produces silica-free water in hot process water softening.



Upward impulses of water produces greater agitation of angular grains, hence Anthrafilt beds are cleaned more effectively.

Anthrafilt No. 1 is usually made in sizes ranging from effectixe size of .60 m.m. to .80 m.m. the uniformity coefficient is less than 1.75 in all sises. We can make smaller sizes or larger sizes, but for special cases only. The remaining sizes of Anthrafilt are as follows:

No. 2. Anthrafilt—3/32"x3/16"
No. 3. Anthrafilt—3/16"x5/16"
No. 4. Anthrafilt—5/16"x9/16"
No. 5. Anthrafilt—9/16"x13/16"
No. 6. Anthrafilt—13/16"x1-5/8"
No. 7. Anthrafilt—1-5/8"x2-7/16"
The above sizes have 20% tolerance.

ANTHRAFILT ECONOMY

When Used in Existing Filtration Plants

Increased capacity with same plant
Decreased volume of wash water
Lower maintenance cost through elimination of ridging, mounding and air binding.

When Used in New Filtration Plants

Lower plant investment
Lower cost per cubic yard
Lower wash water costs
Lower maintenance costs

STUART CORP.

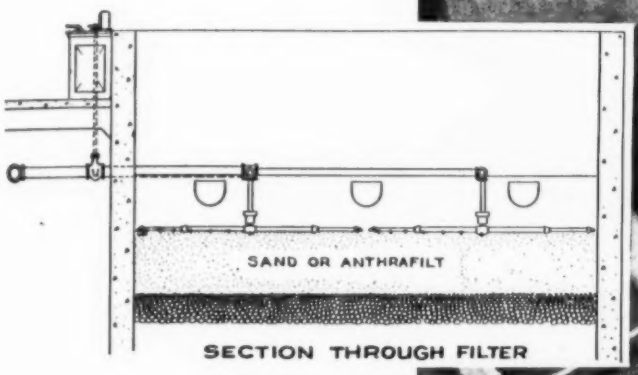
516 NORTH CHARLES ST. BALTIMORE 1, MARYLAND

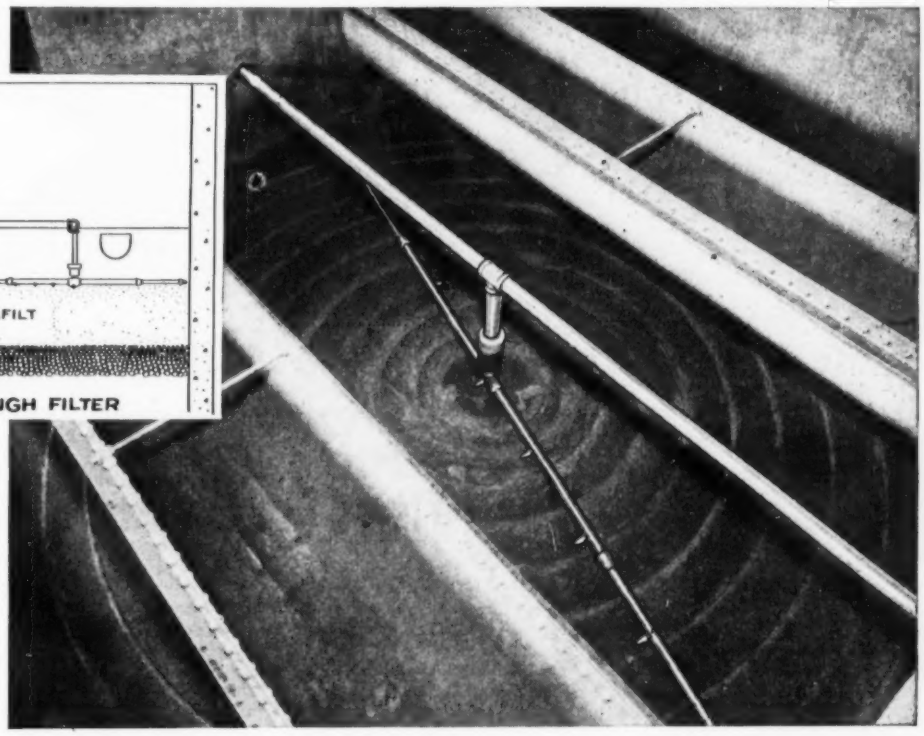
ENGINEERS — MANUFACTURERS AGENTS — CONTRACTORS OF PUBLIC WORK

PRODUCTS

ACTIVATED ALUM **BLACK ALUM**

Palmer Filter Bed Agitators — Adjustable Venturi-Throat Distributing Baffles — Overhead-Drive Flocculation Equipment — Powdered Activated Carbon — Automatic Samplers — Kwik-Way Mixers — Floc Detectors — Package Plants.





The Palmer Filter Bed Agitator (method of washing filter beds) is patented, 2309916 *and* 2309917 *. . . your assurance of effective surface washing.*

PALMER FILTER BED AGITATORS

The Palmer Filter Bed Agitator is a simple and inexpensive device that is being incorporated in new and existing plants to increase the filtration capacity and eliminate mud balls.

Hundreds of municipalities, and a great many industrial companies have Palmer Filter Bed Agitators. The device operates by water at city pressure. High velocity, low volume jet action completely scours the expanded filter medium.

THE TECHNICAL ADVANTAGES OF PALMER SURFACE WASH SYSTEMS

Longer filter runs

Requires an average of 40% less wash water

Completely eliminates mud balls

Eliminates cracking or shrinkage of the beds.

Produces "new" sand after three week's operation

Turns out purer, better tasting water

Low installation cost

No operating cost

More water through the filters

ASK THESE USERS: Norfolk, Va.; Washington, D. C.; Oklahoma City, Okla.; Youngstown, Ohio; Charlotte, N. C.; Laurel, Md.; Buffalo, N. Y.; Allentown, Penn.; Plattsburgh, N. Y.; Erie, Penn.; Lima, Ohio; Wheeling, W. Va. (and hundreds of other installations—both rapid sand and pressure filters.)

Write for free technical bulletins.

4 reasons

why water supply systems use **CALGON***

1. Calgon controls corrosion
2. Calgon stabilizes water following lime softening
3. Calgon prevents scale formation on heating
4. Calgon prevents precipitation of dissolved iron from well waters

—and in all of these uses, Calgon requirements are only a few parts per million.

See the Calgon reference and data page in this section; write for full information concerning your specific problems.

*T.M. Reg. U.S. Pat. Off.

HAGAN HALL BUROMIN CALGON

calgon, inc.

A SUBSIDIARY OF HAGAN CORPORATION

HAGAN BUILDING PITTSBURGH 30, PA.

THE MECHANISM OF CORROSION OF WATER PIPES

And Suggested Formulae for Corrosion Index

By THOMAS M. RIDDICK,
Consulting Engineer and Chemist, New York City

WE HAVE used lime and talked pH adjustment for corrosion control, but the question raised in the author's mind is this: Haven't we come to disregard many of the other significant factors in corrosion? The answer, based on what is to follow, is seemingly that we have.

Atmospheric rusting of steel has been squarely faced by the automotive industry, and their processes of Parkerizing, Bonderizing, etc., are now remarkably successful. It is high time that we of the water works field attempt to more closely correlate theory with practice, standard chemical analyses with specific pipe deterioration, and get away from well worn descriptive alibis such as "soft New England waters."

The suppression or retardation ("prevention" is surely a misnomer) of corrosion is more necessary today than ever before. All indications are that economic conditions will be more stringent for both municipalities and public utilities than heretofore, regardless of the outcome of the war. Both individually and collectively we must tighten our belts another notch and do as best we may with existing supplies and equipment. Household plumbing and the carrying capacity of distribution mains should be judiciously conserved.

A highly corrosive well or surface water that dezincifies yellow brass, removes the galvanizing from steel, and forms the familiar patina on copper tubing should not be delivered into the piping system without treatment simply because no inconvenience has been occasioned to date to the Water Department. If cut sections of household plumbing show relatively rank corrosion, undesirable things are also taking place within the distribution system, although it may not be evident in terms of red water or reduced carrying capacity if pipe lines have been in service less than twenty years. The water works official is the only person in a position to investigate and, if possible, reduce corrosion. Likewise, should it not be that the household plumbing investment of the property owner be given the same consideration as that of the Water Utility.

Two Prevalent Misconceptions

There are two prevalent misconceptions which seem inbred and self-perpetuating in Boards of Water Commissioners. The first is that current water rentals pay for the "Cost of Water." For certain municipalities this may be true, but more often the financial gross intake meets only current operating expenses with little allowance for proper maintenance and depreciation and no consideration is given to bonds retired out of the general tax or by assessment. The writer is familiar with two such water districts having relatively large distribution systems. The rate of $2 per 1,00€ cu. ft. is about one-third the true charge if direct taxation is considered, but the true cost of $6 per 1,000 cu. ft. could not possibly be assessed directly without arousing the consumer's ire.

These facts should definitely be faced in figuring the increased cost which results from treatment for corrosion correction. For example, a certain corrosive well water with a CO_2 content of 12 ppm should be treated. The rate is $2 per M. and the required chemical dosage of lime, soda ash or sodium hydroxide is about 10, 29 and 11 ppm, respectively. If treatment was instituted, the additional cost per 1,000 cu. ft. would be 0.33, 2.7 or 2.4 cents, respectively. However, even the maximum increase (using soda ash) would be less than 1.5 per cent based on the prevailing $2 rate, or one-half of 1 per cent based on the "actual cost" of water to the consumer.

If the property owner was given his choice, i.e., "you may have a natural well water which is rather corrosive to your household plumbing at $2 per M., or a water which is as non-corrosive as is practicable to produce—providing maximum life to your household plumbing—and minimum red water for $2.03 per M.," there is hardly a question of doubt as to his selection.

Though these are the facts, either they have been poorly presented to Water Boards or else human inertia is a costly proposition.

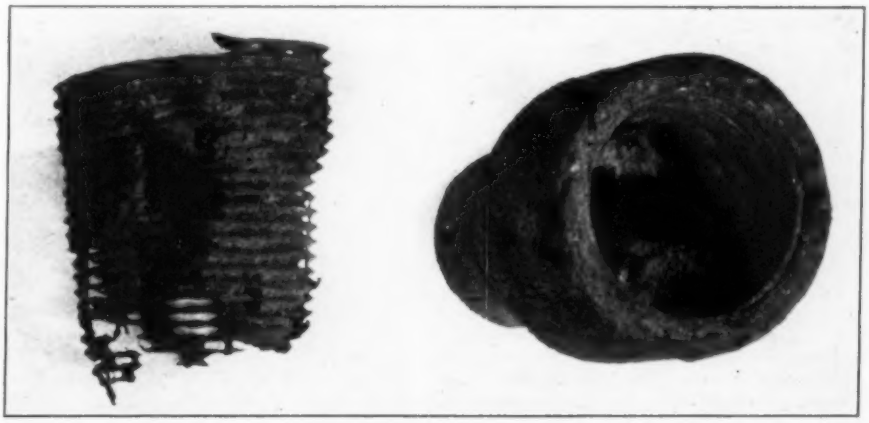
There is one other ghoul permanently stationed behind those Water Board Chairmen who offers the following argument whenever treatment is discussed—"We have *pure natural water*, and don't want any chemicals added." Thereafter the matter is closed. It seems impossible to get across the facts of the case, which are these: There never has been and never will be any "pure" natural water. All ground water contains "chemicals," principally limestone, gypsum, sodium chloride, sodium bicarbonate, and silica, and the gasses—carbon dioxide, oxygen and nitrogen. If a watershed (and all natural water comes from *some* watershed, regardless of its proximity to the well or intake) contains a large amount of gypsum and has marshy areas to contribute carbon dioxide, then a corrosive water is inevitable. If the watershed is composed mostly of limestone (with little gypsum) and few marshy areas, then the mineral content may be high and the water relatively non-corrosive. There are fewer waters in the latter class, and for some of these nature has been over-generous and difficulty may be encountered due to clogged hot water pipes.

The application of chemicals is simply an attempt to produce a "balanced water" applicable to domestic and industrial use, and suitable for conveying in metal pipe. The chemicals added are as "natural" as if nature had created them originally on the watershed.

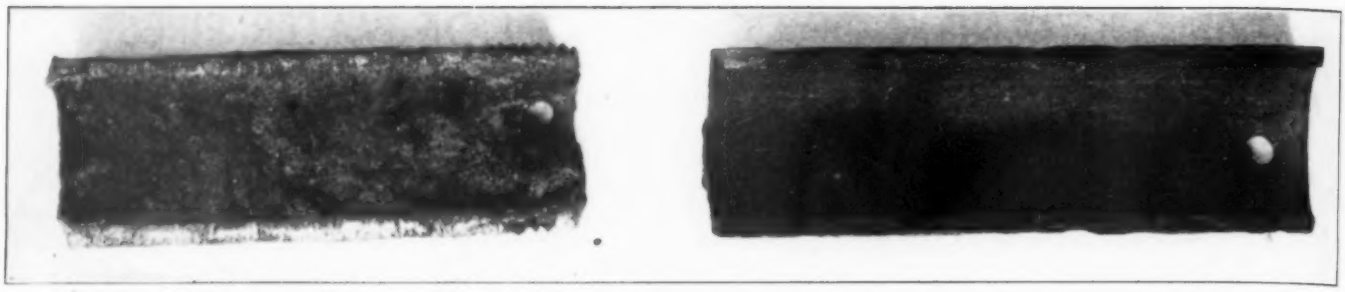
Two Stages of Pipe Life

The useful life of pipe should be divided into two distinct phases. The primary stage is that period during which pipe coatings remain intact or are gradually removed; and the secondary stage involves the direct attack of water on the pipe metal.

Section cut from 4" galvanized wrought iron distribution pipe—service 7 years; note uniform coating of red iron oxide streaked with zinc oxide.



(Left)—Section of 2" riser pipe at entrance to elevated wooden storage tank. Cause of corrosion—low pH, low alkalinity, high sulphate content and high carbon dioxide. (Right)—Corrosion due to use of dissimilar metals—brass vs. wrought iron. Pipe diameter reduced to ⅛ inch.



(Left)—Completely clogged section of cold water pipe—accumulation due to organic matter and iron in unfiltered surface supply plus iron derived from corrosion of distribution mains.

(Right)—Completely dezincified brass service line. Pipe is very brittle and failed through longitudinal split. Cinder fill was contributory cause.

If cast iron and steel pipe coatings are impervious and insoluble, and/or the water is relatively non-corrosive, the first stage may exist indefinitely. These are optimum conditions and result in the absence of "red water" and tuberculation, and pipe carrying capacity is sustained.

However, if coatings are pervious to water or soluble, and allow corrosive water to come in contact with the cast iron or steel, then the formation of creeping tubercles will tend to physically remove the remaining coating, thus exposing more pipe surface to the action of the water. Blisters (small masses of iron oxide overlying pits) form first and grow into tubercles unless the action of the water is inhibitive to the combination of oxygen with iron or steel.

Red water occurs in the second stage, but of far greater importance is the loss in carrying capacity of pipe lines. If water is pumped through transmission mains at relatively high velocity, the increase in power cost can be measured in terms of dollars. If the supply is wholly by gravity, the loss is manifest through reduced pressures on the distribution system and eventually creates a serious hazard from the standpoint of fire protection.

Normal corrosion of cast iron has never been feared from the standpoint of structural deterioration of such pipe to the extent of failure. If this was the case, superintendents and water boards would be mroe alert. Many municipalities, however, stand idly by and allow pipe to tuberculate to such an extent that 12-inch mains are reduced to the equivalent of 10 inches or less, without facing the facts.

This second stage of corrosion is one with which most water departments have to compete, though the use of cement or bituminous enamel linings today give more promise for the future. With pipe coatings removed and pipe surfaces roughened with blisters, all that can be done is to attempt to lessen the corrosivity of the water and its tendency to produce iron rust, which causes consumers' complaints, and to prevent small blisters from growing into large tubercles.

The second stage is more rapid than the first, and the accelerated rate is particularly emphasized after pipe cleaning has been necessitated. There is more than advertising copy in the paint manufacturer's slogan, "Save the surface and you save all." By this token the time to protect the original surface is when a new distribution system is installed rather than 10 to 50 years later after the damage has been done.

Corrosion of galvanized steel and galvanized wrought iron are likewise characterized by two stages of deterioration, and the loss of carrying capacity, the stripping of threads and the occurrence of pin holes are evident remarkably soon after the zinc has been removed.

Copper tubing and yellow or red brass pipe have no protective coating other than the insoluble oxides and carbonates formed by reaction with water. In the case of these pipes there is only one stage of corrosion. It starts with installation and continues until replacement, or until a truly protective coating has been formed. Yellow brass, the most extensively (though unwisely) used of all copper bearing pipe, often requires renewal within five to fifteen years, and there are even instances of severe pitting of copper tubing (particularly class M and L) then necessitated replacement in an even shorter period.

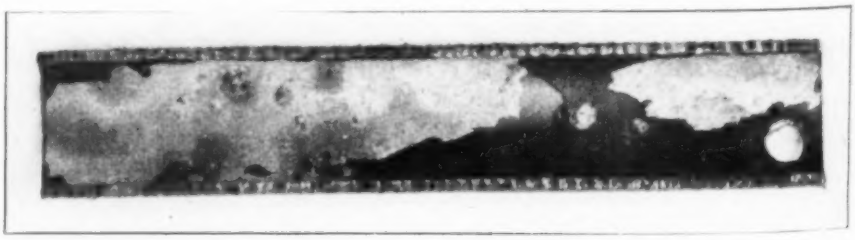
Types of Corrosion Encountered

Let us consider some of the types of corrosion normally encountered in water pipe. For want of a more descriptive term, the small nodules of red iron oxide which form on cast iron pipe will be called "blisters" and sizes above buck-shot will be classified as "tubercles." "Pits" will be considered as those areas (regardless of depth) underlying tubercles, or those exposed indentations created by removal of metal.

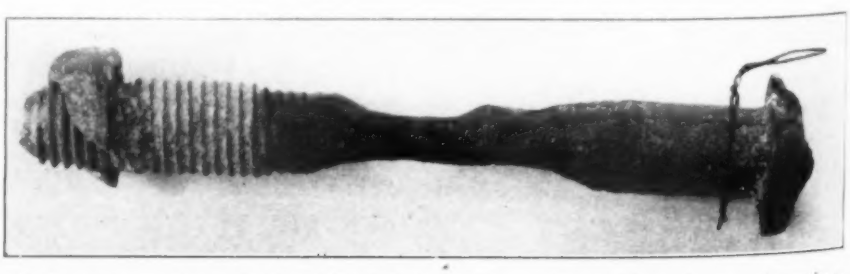
If a blister or tubercle is pried loose from a cast iron pipe wall, we find that the tar or pitch coating is absent or cannot be identified readily. The volume of the tubercle is from three to ten times that of the original iron—or the volume of the "pit." The swelling action, due to formation of the oxide (hydrous oxide) has therefore been responsible not only for the formation of a protrusion which lessens pipe diameter and increases frictional resistance but it has pried away (in its formation) a sizable amount of pipe coating adjacent to the original point of attack, which was initially only microscopic in size.

Composition and Growth of Blisters

The composition of the blister is primarily red iron oxide (Fe_2O_3). On the underside, however, and on the surface of the shallow "pit" we may find a predominance of black crystalline magnetic iron oxide (Fe_3O_4). This can be identified microscopically or by lightly scraping the underside of a freshly removed tubercle and subjecting the crystals to the action of a bar magnet. It must be that the magnetic oxide of iron is the first product formed, since it lies next to the metal surface, and that the Fe_2O_3 is the final stage of oxidation. It is possible that the very



Copper tubing after 5 years' service. Failed through pitting. Note heavy formation of copper carbonate. Cause, possibly electrolysis.



Acid type corrosion of ¾" coupling bolt for Universal Pipe. Note absence of any iron oxide. Failure probably due to small amount of cinders in fill.

first stage was the lower oxide, FeO. The three stages of oxidation in their simplest expressions would be:

$2\,Fe + O_2 = 2\,FeO$ (ferrous oxide)

$6\,FeO + O_2 = 2\,Fe_3O_4$ (magnetic iron oxide)

$4\,Fe_3O_4 + O_2 = 6\,Fe_2O_3$ (ferric oxide)

If blisters were "watertight," they would cease to grow from within. Enlargement of small blisters into large tubercles is probably accomplished in three ways:

1. Growth from *without*, by deposit of iron oxide derived from the water per se, or from corrosion of the distribution system by the water en route.
2. Growth of the tubercle from *within* by the passage of water (carrying oxygen) through the amorphous red iron oxide to the pipe metal.
3. Growth of the tubercle from *within* by the passage of water (carrying oxygen) through the peripheral seal of the tubercle, to the pipe metal.

In the first stage of growth, it is probable that oxygen gains admission through the relatively thin coating of amorphous red oxide. As growth advances, more oxygen is admitted around the ever enlarging periphery of the nodule, and less through the body of the growth. The nodule is generally held to the pipe metal by the crystalline interlocking of the magnetic iron. When tubercles are removed by "prying loose," they generally remain intact, which indicates that the plane of structural weakness lies in the under zone of magnetic iron next to the metal. It is logical to presume that a thin crystalline plane offers less resistance to the passage of water than the dense mass of red iron oxide forming the body of the nodule.

What is the property of red iron oxide which holds it together in a ceramic like mass? The hydrous or anhydrous forms of the pure compound will not agglomerate and harden at normal temperatures. When tubercles are ground in a mortar and analyzed, the silica content (or what we differentiate as silica) is several per cent. Silicates are the most widely used cementing agents in both nature and industry, and it is logical to assume that this is one of the factors which is responsible (perhaps fortunately so) for tubercle formation. If water has a pronounced tendency to corrode metal, it is preferable to have it form a protective scale rather than to continuously discharge ferrous bicarbonate or iron oxide to the consumer. If silica is present in the tubercle, its source must be the water itself if no silicates have intentionally been applied to suppress corrosion.

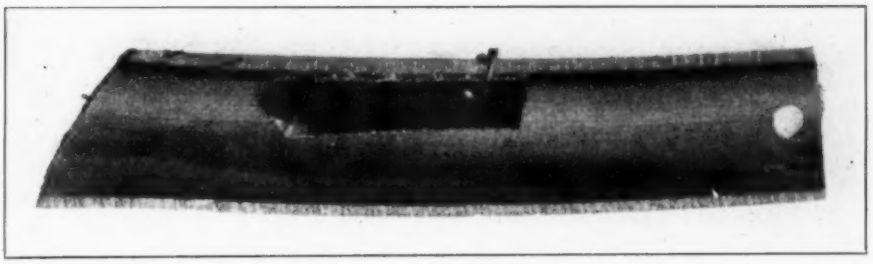
Again, It Pays to Save the Surface

If water treatment is necessary, it should begin when the distribution system is installed. Although little published research exists on the subject, it is likely that high carbon dioxide and low pH has a tendency to dissolve and penetrate pipe coatings more rapidly than neutral or alkaline waters.

Once pipe coatings are removed, water treatment may "reduce" but never "eliminate" corrosion. The manner of inhibiting the further oxidation of iron or steel seems to be:

1. To precipitate or force calcium carbonate out of solution to form a "protective film" or "protective coating" on the walls of the pipe.
2. To lessen the tendency of iron to dissolve and/or unite with the oxygen content of the water.
3. To make existing blisters, tubercles, or coatings of iron oxide more impervious and impenetrable, thereby more effectively preventing the contact of the oxygen carrying water with the pipe metal.

The writer believes that the first principle has been over-em-



Excellent example of nature's "overtreatment" of a well water. Protective scale of calcium and magnesium carbonate and sulphate formed in a hot water line. Jet black color, due to manganese. Removed from service due to clogging.

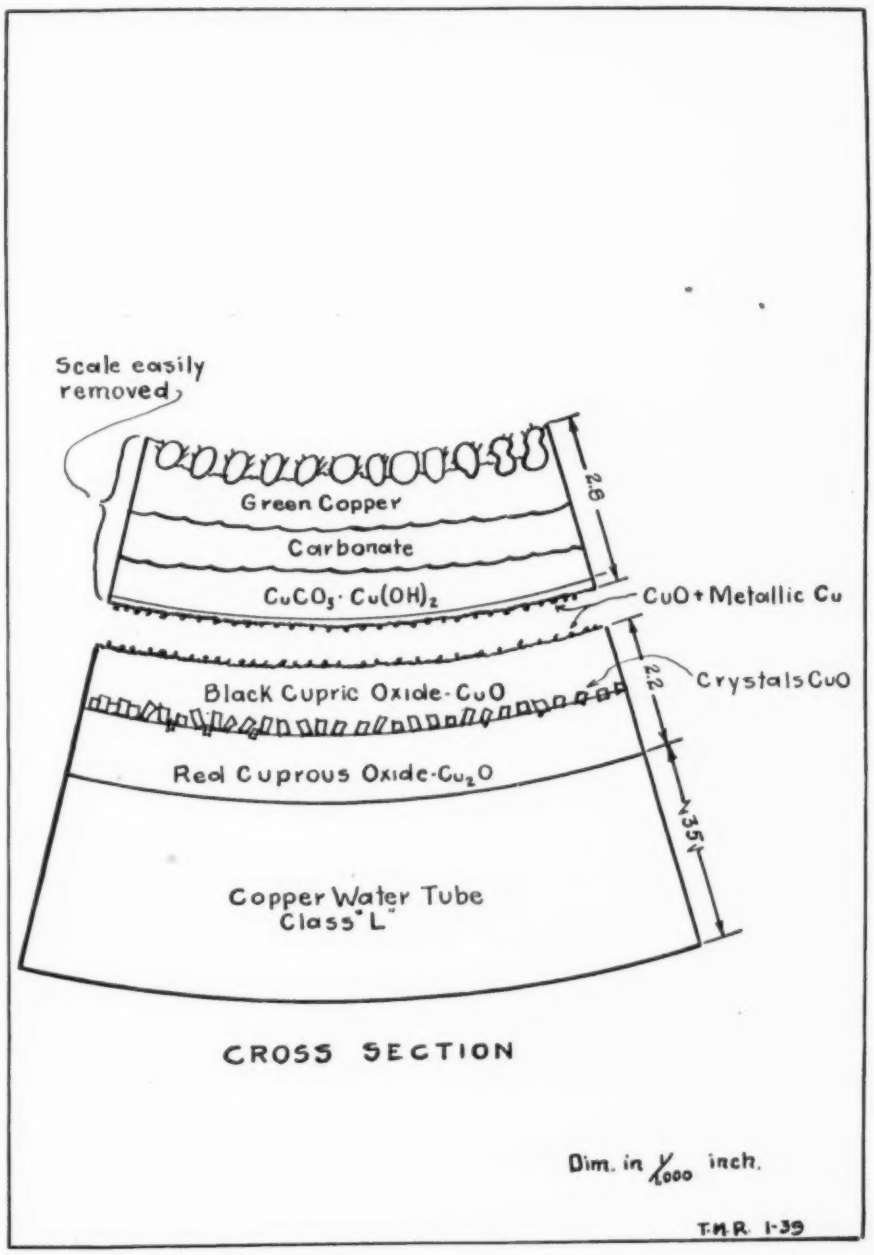
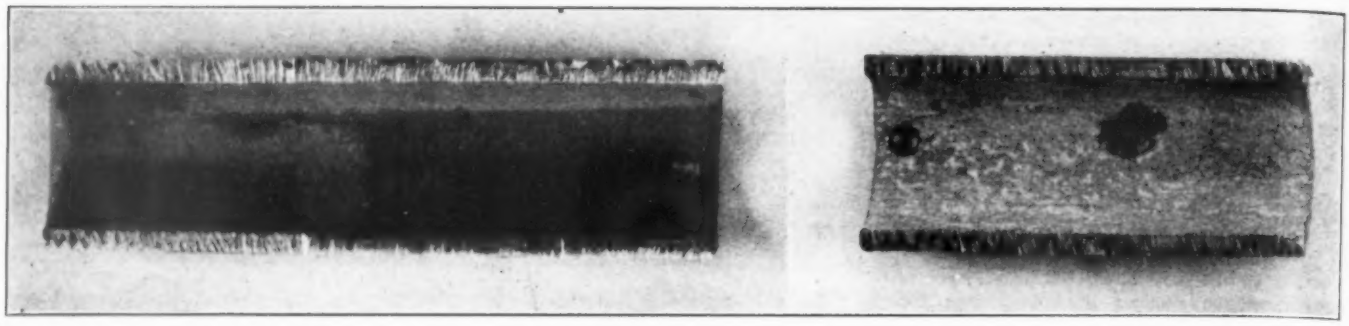


Plate 1—Sketch of a Section Cut From Copper Tubing Which Suffered Severe Corrosion

(Under the microscope this section, as sketched, revealed the mechanism and end products of the progressive corrosion as explained in the text.)



(Left)—Split section of yellow brass house plumbing completely protected by coating of iron oxide from the distribution main. (Right)—Dezincification of galvanized wrought iron.

phasized. There are certain natural non-corrosive waters which contain insufficient mineral salts, and have pH values entirely too low, to ever force calcium carbonate out of solution. Their non-corrosive properties must surely be derived from the two principles last mentioned. If alkalinity, pH and calcium content is maintained at a point to provide *adequate* "film protection" to cold water lines in winter months, then the change in temperature from between 32 and 40° F. to between 140 and 160° F. should clog a lot more hot water systems than we hear about, and consumers are never remiss in voicing such complaints to the water utility.

The More Important Functions of Treatment

The writer feels that the more important functions of treatment are to reduce the tendency of the water-borne oxygen to unite with iron, and to further cement or "waterproof" the iron oxide already present in the pipe, whether it be in the form of a surface film, blisters or tubercles.

This cementing action is quite apparent when we observe water containing less than a "trace" of iron, if any, drawn from mains coated with tubercles to a thickness greater than one inch.

Galvanized pipe, either steel or wrought iron, first exposes a zinc surface to the attacking water. Primary corrosion results in the formation of both zinc oxide and carbonate. It is likely that the oxide is first formed, which might of itself form a protective coating. Carbon dioxide, however, seems to combine readily with the oxide to form a coarse crystalline carbonate, which is removed by gradual solution as well as breaking away from the pipe walls in small pieces.

Once the protective zinc has been attacked sufficiently to allow water to reach the wrought iron or steel, the upheaval of scale is more rapid due to the bulking effect of iron oxide. Thereafter, the pipe walls become coated with blisters or scale of red iron oxide, and subsequent deterioration seems comparable to cast iron tuberculation. Steel is, as a rule, attacked more rapidly than wrought iron, and its life may be quite short after complete removal of zinc.

Zinc is more resistant to corrosion than iron or steel, else its application to pipe surfaces would be pointless. Again the emphasis should be on preservation of the original surface.

Red brass, yellow brass, and copper tubing have no protective coating other than the surface film of the metal itself. Yellow brass pipe is unreliable for most waters and should be barred from plumbing use. Gradual deterioration is through the removal of the zinc to form oxide and carbonate scales although a sizable amount of copper is also present. Failure occurs

1. At the pipe threads, particularly if these are cut deep.
2. By gradual reduction of wall thickness, and pitting to produce "pin holes."
3. By complete dezincification, which leaves the copper in a semi-crystalline state.

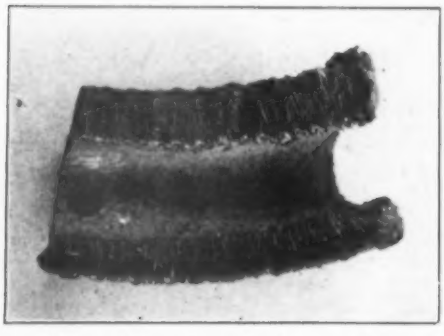
Tell-Tale Indications of Yellow Brass Deterioration

The occurrence of a "white powder" at joints of yellow brass is common, but a visual inspection of piping in service for several years will give little indication whether the powder is zinc carbonate or white lead oxide—a compound often used in "pipe dope." Microchemical analysis gives ready identification, however, and if zinc is predominant, the remaining years of useful service of the yellow brass are numbered.

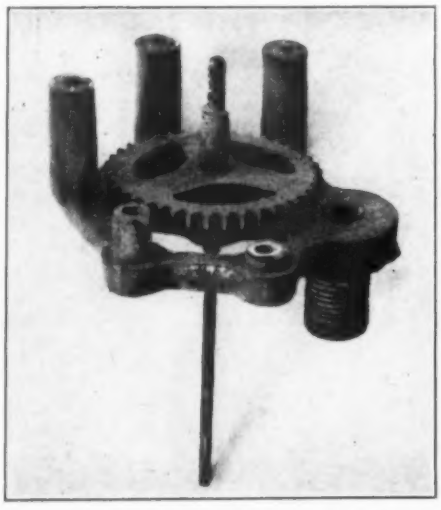
Several years ago the writer instituted treatment for an estate where yellow brass was used throughout, and many sections had "pin hole leaks," necessitating pipe replacement. Copper carbonate was present in sufficient amounts to impart a heavy green stain to laundered goods and to porcelain beneath dripping faucets. The complete neutralization of CO_2 and raising the alkalinity about 40 ppm completely inhibited the further discharge of copper carbonate, and since no leaks have subsequently occurred, it is reasonable to state that corrosion or further dezincification has been very greatly reduced.

Complete dezincification with embrittlement of pipe metal is not common. It is possible, however, and small fragments could easily be broken from one specimen examined by the writer. The plane of fracture showed no metallic copper whatsoever, and this could only be observed by cutting through the specimen with a saw.

Red brass, containing 15 per cent zinc, seems more resistant to corrosion even than copper tubing, or expressed conversely, some waters very low in mineral solids and high in carbon dioxide attack copper tubing readily, but red brass either slowly or not at all. For the less corrosive waters, little comparison can be drawn since the life of both is, and should be, for a much longer period than we have on record today.



Impervious green coating on lead service pipe.



Corrosion of meter parts. Brass frame, shaft and gear coated with iron oxide.

Meter disc chamber badly pitted and encrusted with copper carbonate.

Some Observations of Corrosion of Copper Tubing

A section of badly corroded type L copper tubing, which had pitted-through or "pinholed" in spots, is sketched to scale in Plate 1. The surface scale, which was easily removed in long cylindrical rolls, was green copper carbonate. This was bound to the scale adhering to the pipe wall by black cupric oxide, which was distinctly crystalline in structure. The method of attachment was therefore quite parallel to that of tubercles on cast iron pipe walls. Beneath the cupric oxide was a layer of red cuprous oxide Cu_2O, which apparently was being formed from the metal of the tubing. This progressive oxidation somewhat substantiates the conclusion that the first oxide formed in tuberculation of cast iron pipe was ferrous oxide FeO, which is not so readily identified as the red cuprous oxide, Cu_2O.

The order of oxide formation, expressed in simplest terms, is as follows:

$4\,Cu + O_2 = 2\,Cu_2O$ (cuprous oxide)
$2\,Cu_2O + O_2 = 4\,CuO$ (cupric oxide)
$2\,CuO + H_2CO_3 = CuCO_3 \cdot Cu(OH)_2$ (cupric carbonate)

If a standard mineral analysis had been made of the ***removable*** scale only, the stages of oxidation or carbonation would not have been manifest. This suggests the necessity of employing microchemical methods, as was done in this instance, and the need of a more fundamental study of the progressive stages of corrosion.

In the absence of carbon dioxide, it is probable that only cuprous and/or cupric oxide would be formed, which serve far better as a protective film than the more porous cupric carbonate.

This conclusion points strongly to the presence of carbon dioxide as a potent factor in corrosion, but it does *not* explain why *some* supplies containing high amounts of CO_2 do not actively attack copper tubing.

Practical Observations vs Theory

The writer has long felt that the approach to corrosion in the water works field has followed too much the same line of reasoning. And, axioms (some formulated years ago for specific supplies) have too generally been accepted and applied. There are no two waters the same, and it is only by viewing corrosion of many supplies that we may form a concept of the fundamental underlying principles.

It is often true that practice precedes theory, and with this in mind, the writer has tried to disregard some of our accepted tenets and evolve a rational approach from the standpoint of *evidence* rather than theoretical reasongin and what are accepted as chemical laws.

If we have a practical knowledge of many supplies, natural or treated, they may be classified as "non-corrosive," "corrosive" and "very corrosive," based only on (1) frequency of hydrant flushing on dead ends and time required for hydrants to flush "clean," (2) occurrence of red water on the distribution system, (3) life of galvanized steel, galvanized wrought iron, copper, red and yellow brass pipe, and hot water boilers, (4) tuberculation of mains, (5) loss of pipe carrying capacity, (6) stains on porcelain, (7) occurrence of brown or green stains on laundered materials, (8) dezincification of galvanized steel or wrought iron, yellow brass pipe, etc., etc.

If the chemical analyses for such classified waters are compared, we find little if any correlation for any *one* constituent and *this particularly applies to pH.* But considering the mineral and gaseous components, a general pattern seems to be evolved.

If we occasionally find natural, untreated, well and surface supplies which are relatively non-corrosive, should we not consider them somewhat as a criterion when we begin to alter the characteristics of water by the addition of lime, soda ash, caustic soda, silicate, and the aluminum and iron coagulants?

I do not infer that nature cannot be improved upon. It can, as is evidenced by the applications of vitamins to aid plant growth, but until we have at least *equaled* natural processes, let us not try to improve upon them.

The physical and chemical tests which should be employed in the evaluation of any water are: Turbidity, Color, Odor, Carbon Dioxide, Alkalinity, pH, Hardness, Iron, Manganese, the Nitrogen Determinations, Chlorides, Temperature, Dissolved Oxygen, Silica, and Solids.

The complete mineral analysis is far too time consuming to ever be used from a practical standpoint, unless a lot more time and money is expended than heretofore.

To judge the corrosive qualities of a water *per se* (not the *effects* of corrosion) the writer believes that the following tell most of the story: Carbon Dioxide, Alkalinity, Hardness, Silica, Dissolved Oxygen, Chlorides and Nitrates.

The two constituents last classified are generally present in such low amounts (in Atlantic coastal supplies at least) as to render their inclusion rather dubious. Oxygen can only be determined accurately in the field and is not a "routine" test. Silica should definitely be included in routine examinations, although the method of analysis is of doubtful accuracy.

Three Empirical Formulae Evolved

The writer has evolved three purely empirical formulate to numerically express the corrosive tendencies of water, based on correlation of Standard Methods tests with the physical manifestations of corrosion previously listed.

They definitely take hydrogen ion concentration (pH) into consideration by the inclusion of Carbon Dioxide and Alkalinity, and I believe evaluate their true importance more accurately than does the pH test.

Formula 1 is most applicable to routine analyses as performed by most commercial and state laboratories, and is as follows (analytical values are expressed in ppm.):

$$(1)\ \text{Corrosion Index} = [CO_2 + \tfrac{1}{2}\,(\text{Har.} - \text{Alk.}) + Cl^- + 2N]\,\frac{75}{\text{Alk.}}$$

It gives numerical values ranging from about 5 to 150, which are evaluated by the writer as follows:

0-5	Extremely non-corrosive
6-25	Non-corrosive
26-50	Moderately corrosive
51-75	Corrosive
76-100	Very corrosive
101+.	Extremely corrosive.

This formula is generally applicable to waters on the eastern seaboard. It may apply or may be totally inapplicable to those of the west or midwest. It holds primarily for natural waters but seems to give good interpretations for treated supplies.

There are two other factors of prime importance which have been omitted since many laboratories do not make these tests as routine—they are Silica and Dissolved Oxygen.

When the silica test is made, the following correction may be applied:

$$(2)\ \text{Corrosion Index} = \text{C.I. (1)} \times \frac{10}{SiO_2}$$

If dissolved oxygen is also included, the formula is:

$$(3)\ \text{Corrosion Index} = \text{C.I. (1)} \times \frac{10}{SiO_2} \times \frac{\text{D.O.} + 2}{\text{Sat. D.O.}}$$

$$\text{or} = \text{C.I. (2)} \times \frac{\text{D.O.} + 2}{\text{Sat. D.O.}}$$

It is observed that the formulas particularly stress total alkalinity and non-carbonate hardness. The writer is firmly convinced that the latter, which is often magnesium sulphate, is a potent factor in corrosion.

Several natural "non-corrosive" waters are listed in Table 1. pH values are below those normally carried in alkali treated waters and range from 6.3 to 7.8 Corrosion indices are uniformly low, however, except for the well water having a value of 62. The inhibiting factor in this case is naturally the low dissolved oxygen. Obviously formula 3 would have been more applicable. The only common characteristic of the group is *low non-carbonate hardness.* Although these natural waters are listed as non-corrosive, there is no doubt but that complete neutralization of carbon dioxide and the maintenance of several parts per million of carbonate alkalinity would have rendered them still less aggressive.

Several extremely corrosive waters are shown in Table 2.

Again the only common characteristic is high sulphate content, though the effect of low alkalinity seems pronounced. In the reservoir water and the shallow well supply last listed, the writer is convinced that sufficient alkalinity could not be supplied by lime without excessive pH, and in these instances soda ash or caustic soda would be the preferable chemical to apply.

It has been known for some time that waters low in carbon dioxide and alkalinity could not be given sufficient lime to form a protective coating, but the writer feels that there is some further principle involved which may be roughly expressed as a hardness-alkalinity or carbonate-sulphate ratio.

An example of the application of lime or soda ash to alum treated water, either before or after secondary aeration, is shown in Table 3.

Here is indicated the advisability of adding lime or soda ash *before* rather than after secondary aeration. The Index is probably somewhat exaggerated, though plant operation showed that corrosion was reduced by substituting soda ash for lime in post

aeration treatment, and a split dosage of pre lime and post soda ash has been instituted.

Based on correlation of chemical analyses with pipe deterioration, the following factors tend to reduce corrosion:

(1) Low non-carbonate hardness, or low sulfate content.
(2) High alkalinity.
(3) High silica content.
(4) Low carbon dioxide.
(5) Low oxygen concentration.
(6) Low temperature.

Those tending to accelerate corrosion are the converse of the above.

The writer wishes to emphasize that the empirical corrosion indices listed were prepared on a cut and try basis over a period of years and are naturally subject to discrepancies and to change. They constitute a "rule of thumb" method for evaluating the corrosive qualities of a water, based on normal chemical analyses, and admittedly there is no phase of water treatment that can be competently handled on such a basis.

The formulae are presented with the hope they may elicit further practical research, and that a sufficient number of operators, chemists and superintendents will apply them, to either substantiate, improve, or entirely discredit the Indices.

TABLE 1—RELATIVELY NON-CORROSIVE WATERS

Results in parts per million

Source	River	Spring	Deep Well	Deep Well	Deep Well	Spring
Carbon Dioxide	1	1.5	18	16	8	0
Alk. (Bicarb.)	100	66	30	92	130	28
Hardness	104	76	34	88	131	28
Chlorides	4	4	5	5	9	3
Nitrates	1	0.4	0	0	1	0
pH	7.9	7.3	6.3	6.8	7.4	7.8
Silica	..	..	7	..	..	..
Dissolved Oxygen	..	..	2.4	..	..	..
Corrosion Index*	7	13	62	17	11	8

*Computed with formula (1).

TABLE 2—VERY CORROSIVE WATERS

Results in pa. ts per million

Source	Shallow Well	Shallow Well	Reservoir	Deep Well	Deep Well	Shallow Well
Carbon Dioxide	11	18	3	14	18	26
Alk. (Bicarb.)	5	9	9	18	34	8
Hardness	60	22	20	34	60	46
Chlorides	20	5	2	3	5	13
Nitrates	11	1	0	0.5	1	1
pH	5.5	5.8	6.6	6.1	6.6	5.5
Silica	..	2	5	6	..	..
Corrosion Ind.*	1050	267	92	108	82	560

*Computed with formula (1).

TABLE 3—EXAMPLE OF EXTREME VARIATION IN CORROSION INDICES DUE TO POINT OF APPLICATION OF ALKALI

Results in ppm.

	Raw W. After Aeration	Filtered Water	Filt. W. After Sec. Aer.	Finished Water—Lime Before Sec. Aer.	Finished Water—Lime After Sec. Aer.	Finished Water—Soda Ash Before Sec. Aer.	Finished Water—Soda Ash After Sec. Aer.
Chem. Dosage, ppm	..	..	..	13	4	36	10
CO_2	2	15	4	0	0	0	0
Alk. (Bicarb.)	38	38	38	56	43	38	38
Hardness	18	3	3	21	8	37	12
Chlorides	3	3	3	3	3	3	3
Nitrates	1	1	1	1	1	1	1
D.O.	Sat.	Sat.	Sat.	Sat.	Sat.	Sat.	Sat.
pH	6.9	5.6	6.0	7.9	7.9	7.9	7.9
Corrosion Ind.*	71	940	660	80	210	11	110

*Computed with formula (1).

COPPER AND HEALTH*

The effect of copper on health is a subject of such importance to all users of copper and brass and copper sulphate for algae control, that the conclusions in an article read before The New England Water Works Association are given below:

1. The copper content of domestic drinking water after passing through copper or brass pipe or tubing, even if a slight amount of copper is taken into solution, is not harmful to health. It may indeed be beneficial.

2. All water supplies intended for domestic use after passing through a proper installation of copper or brass pipe or tubing will contain but a small percentage of the permissible copper content, if any at all.

3. The permissible copper content of domestic water based on a consumption of one gallon of water a day should apparently not be greater than 20 p.p.m.

4. It is unlikely that health will be injured by copper because, where the copper content is above 5 p.p.m., the taste of the water will generally be so disagreeable that it will be virtually impossible to drink it.

5. No anxiety need be felt about a proper installation of copper or brass pipe or tubing, because it has been shown that with acid water having a pH value of about 6.5, the copper content is generally only about 0.5 p.p.m., even after standing in the pipe lines for an appreciable length of time.

6. The treatment of reservoirs with copper sulphate to rid them of undesirable microscopic growths has no injurious effect on health.

*Journal N. E. W. W. A., 44: 4, December, 1930.

TUBERCULATION MEASUREMENT AS AN INDEX OF CORROSION AND CORROSION CONTROL*

By EDWIN W. BARBEE
Water Purif. Engr., Water Dept., San Francisco, Calif.

IN AN attempt to measure the relative corrosiveness of San Francisco water and to determine the most efficient and practical corrective treatment, a series of studies have been made by the city water department. Except for the aeration of one source of supply, the only treatment applied to the water at the present time is disinfection. Natural storage and strict watershed sanitation, combined with chlorination, have provided an acceptable water.

The San Francisco supply is derived from three sources: the Hetch Hetchy project, the Alameda system and the Peninsula system. Consumption, which increased rapidly during the war years, now exceeds 100 mgd. The Hetch Hetchy supply has provided for these increases and now supplies more than half the consumer demand, although most of the water is mixed with local supplies before actual delivery to the consumers.

Table I shows typical analyses of the Hetch Hetchy supply and the Crystal Springs storage reservoir. The change in corrosive character is indicated by Langelier's saturation index, which has decreased from—0.2 to 0.9. Corrosion complaints and complaints of rusty water have increased. Future increases in the use of soft Hetch Hetchy water without anti-corrosion treatment would further aggravate the problem. Treatment of this water now seems to be assured, however, and actual operations are expected to begin in about a year.

Preliminary Study

Prerequisites to the corrosion studies were a knowledge of the variables influ-

*From *Jour. Amer. W. W. Assn.*, Mar., 1947. Reprinted by permission of the A.W.W.A.

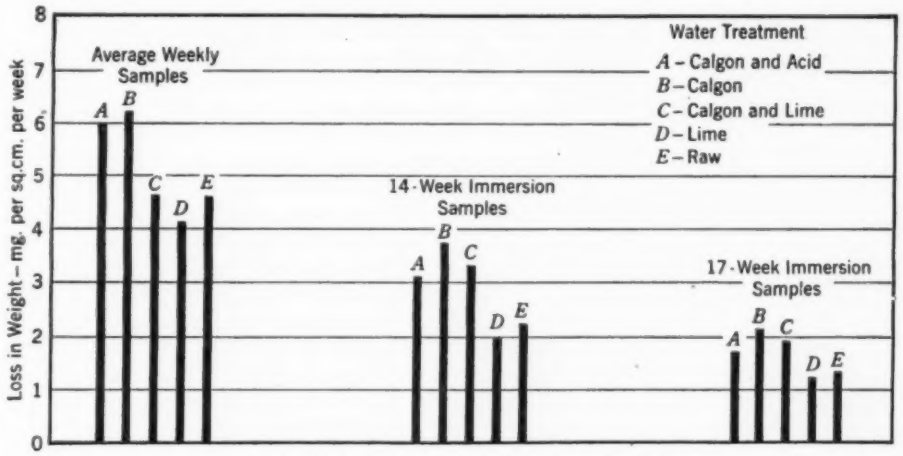


Fig. 1. Weight Loss of Corrosion Specimens

TABLE I
Typical Mineral Analyses of San Francisco Waters

Source	Crystal Springs	Hetch Hetchy Reservoir	Crystal Springs	Hetch Hetchy Moccasin	Crystal Springs
Date Sampled	7/23/34	8/27/36	9/5/39	12/13/45	4/8/46
Conductivity	38.5	1.97	16.9	2.0	16.2
pH	7.6	6.4	7.7	7.1	7.7
Dissolved solids, ppm.	195.0	14.0	107.0	20.0	96.0
Silica and insolubles, ppm.	13.0	3.8	4.0	6.2	5.6
Sodium (Na), ppm.	19.0	0.0	7.6	1.0	8.6
Calcium (Ca), ppm.	39.0	1.1	17.5	2.7	14.9
Magnesium (Mg), ppm.	16.0	1.4	6.4	1.0	5.8
Iron (Fe), ppm.	0.02	0.025	0	0.02	0.01
Aluminum (Al), ppm.	3.0	0.56	0.6	0.07	0.4
Bicarbonate (HCO_3), ppm.	177.0	6.0	73.0	9.8	68.0
Sulfate (SO_4), ppm.	28.0	1.6	15.5	0.8	11.9
Chloride (Cl), ppm.	21.0	1.0	8.0	3.0	9.0
Hardness as $CaCO_3$, ppm.	163.0	11.0	71.0	17.0	61.0
Alkalinity, p m.	145.0	5.0	60.0	8.0	56.0
pHs	7.8	10.7	8.5	10.1	8.6
Saturation index (pH — pHs)	—0.2	—4.3	—0.8	—3.0	—0.9

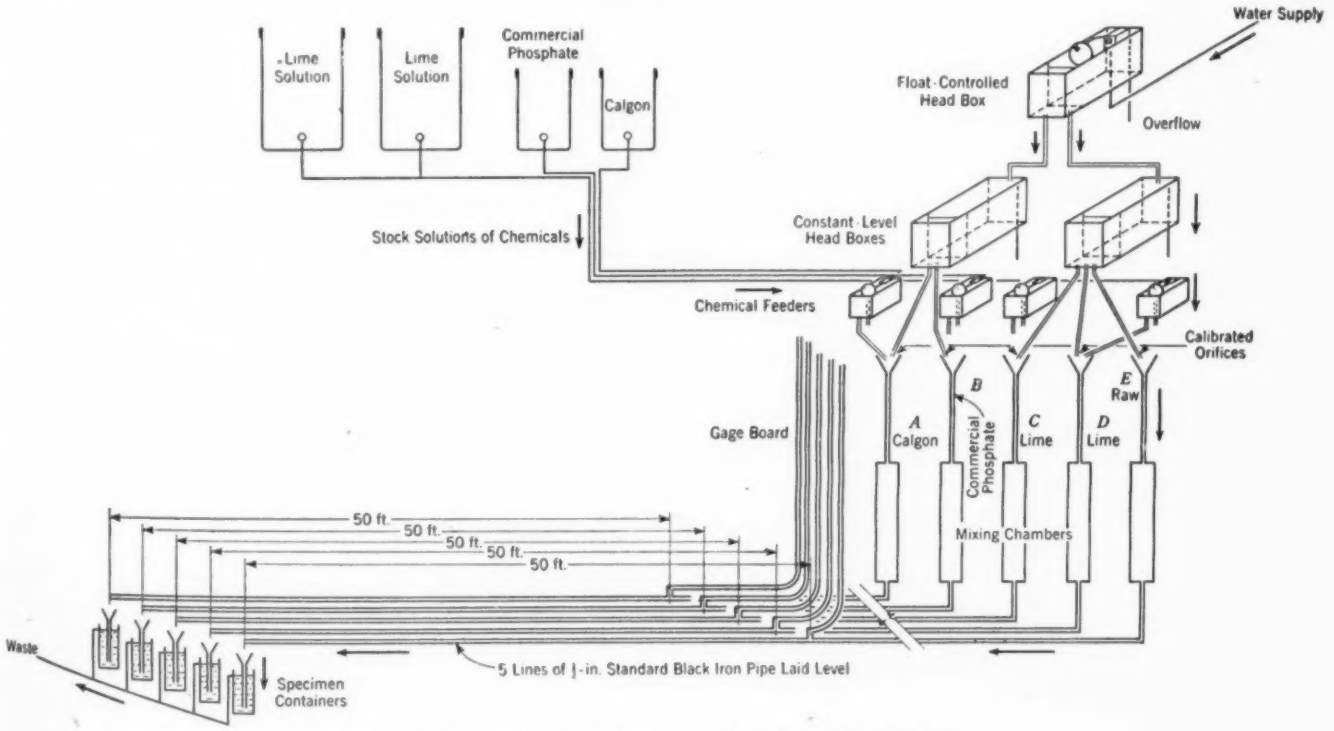


Fig. 2. Arrangement of Equipment for Corrosion Studies

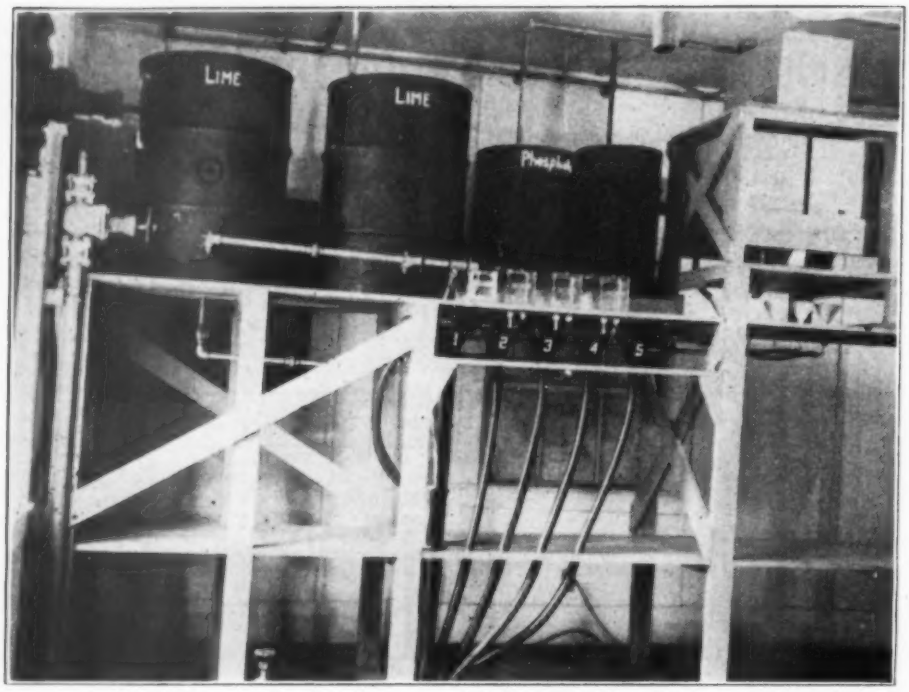


Fig. 3. Chemical Feeds and Constant-Head Boxes

encing the rate of corrosion and experimental apparatus that would give a quantitative expression of the results obtained. The corrective treatment, from a water works point of view, would be that necessary to preserve the flow coefficients and useful life of pipelines and other water supply appurtenances. The apparatus had to show the combined influences of the factors determining the amount and rate of corrosion; these variables include: (1) oxygen concentration, (2) by-products of corrosion, (3) hydrogen ion concentration, (4) alkalinity, (5) pipe material, (6) temperature and (7) film-forming salts and protective coatings.

Corrective treatment utilizing lime or phosphate offered the most promising results.

It was preferred that the quantitative results obtained correlate with established values in the literature and reflect field conditions. Such testing criteria include: (1) loss in weight and penetration, (2) decrease in dissolved oxygen, (3) reduction in cross-sectional area and (4) resistance to flow measurements. It was desirable that the testing equipment require a minimum of attention, be easily duplicated and allow for changes in treatment and control necessary for determining the effects of the variables influencing the rate of corrosion.

Previous work had been done by the department in 1941, utilizing loss in weight and mean penetration values. The results obtained could not be directly correlated with carrying capacity, age or serviceability. Fig. 1 shows the results obtained with one set of corrosion specimens. The unit used is loss in weight in milligrams per square centimeter per week. The average weekly bar graphs represent average values for specimens taken out, cleaned, weighed and re-immersed each week. The 14-week immersion graphs represent specimens submerged for 14 weeks, and the 17-week graphs show the loss in weight for a 17-week immersion period. A certain degree of protection was afforded by the rust coating of the specimens that were kept submerged, as shown by the higher rate of loss in the specimens cleaned and re-immersed each week. Loss in weight values varied in the *A* samples from 1.7 to 6.0 mg. per sq. cm. per week, depending upon the degree of protection afforded by the products of corrosion. On the other hand, the best treatment produced only 0.2 to 0.5 mg. per sq. cm. per week less loss of weight than the next most effective treatment.

Experimental Procedure

Fig. 2 is a diagrammatic sketch of the corrosion test equipment utilized in the

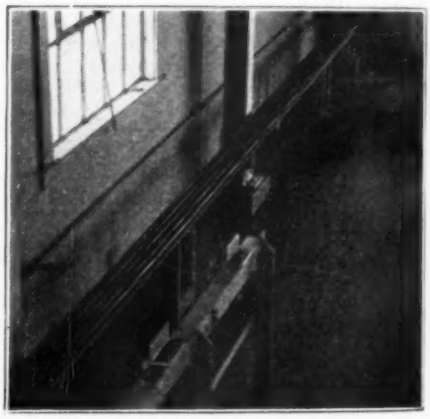


Fig. 3A. Pipe Lines in Study

studies. Head loss is used as the index of resistance to flow, and the amount of tuberculation is reflected directly in the increased head necessary to pass the calibrated quantity of water. This arrangement, part of which is also shown in Fig. 3 and Fig. 3A, should allow a determination of the effect of most of the variables affecting corrosion. Dissolved oxygen, pH, alkalinity and temperature determinations can be made directly, and the pipe material, of course, is chosen. Film-forming characteristics of the easily controlled chemical feeds are reflected in the head losses, and the physical and chemical characteristics of the film can be determined by analysis and inspection on completion of the run. The flows can be calibrated and readily checked; their velocities are comparable to those encountered in practice. Loss in weight and mean penetration values can be determined from cut sections of the test run or from the suspended specimens. What decrease there is in dissolved oxygen can readily be determined. With the use of dye, the actual velocity can be found; this, with the calibrated flow, will give an effective cross-sectional area. The decrease in area can be correlated with loss of head, and the final results expressed in flow coefficients.

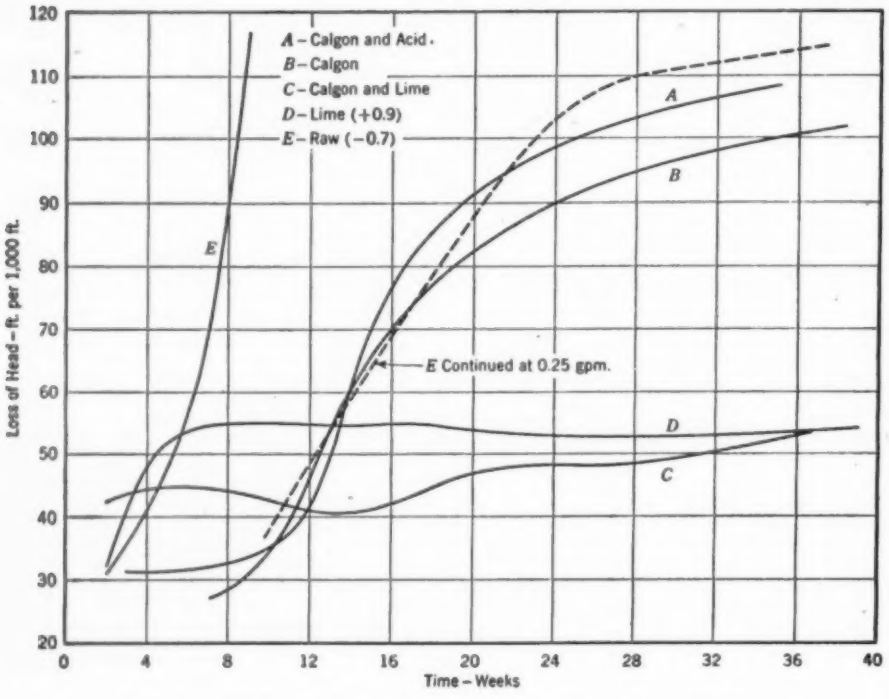


Fig. 4. Head Losses With Crystal Springs Water in ⅜-in. Pipe

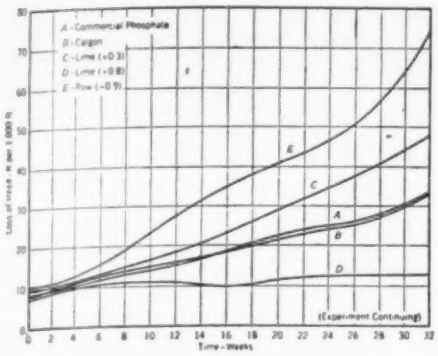


Fig. 5. Head Losses With Crystal Springs Water in ½-in. Pipe

This study was initiated in 1941, discontinued in 1942 and resumed in 1946. The 1941 work was with Crystal Springs water and the 1946 studies with Hetch Hetchy and Crystal Springs water. The standard layout uses ½-in. black iron pipe and a calibrated flow of 0.5 gpm. The 1941 experiments were made using ⅜-in. pipe and 0.5 gpm. flows. The experiment is continuing.

Curves Obtained

Head losses are plotted in Fig. 4 for the 1941 test with Crystal Springs water. Figure 5 shows the head losses for 1946 tests with Crystal Springs water, and Fig. 6 gives the plotted curves showing head losses using Hetch Hetchy water in 1946. In all figures *E* represents the untreated raw water line; the other lines carry treated water. A dosage of 1 ppm. was used in all phosphate-treated lines. Where lime was used, the treatment was constant to give the saturation index noted in parentheses.

Using the head loss, flow and pipe data for each of the three sets of conditions, the flow coefficients (*C*) in the Williams-Hazen formula were computed. Fig. 7, 8 and 9 show time plotted against coefficient *C* for each of the pipelines under the three sets of conditions. An attempt was made to correlate the per cent of *C* decrease in time with the saturation index for all lines using raw and lime-treated waters. These curves are shown in Fig. 10. In general, the relationship bears out Langelier's statement of "directional tendency and driving force" when applying the saturation index to specific pipe corrosion. It should be pointed out that the comparison made in Fig. 10 is for a short period of time, and final equilibrium has not been reached in the 1946 experiments.

Test Conditions

A discussion of the conditions under which these data were collected should place particular emphasis on those factors known to accelerate corrosion. Commercial standard black iron pipe was laid level, cleaned by concentrated sulfuric acid with an inhibitor and brushed. Care was taken to prevent galvanic action from seriously affecting the results by insulating the lines.

Dissolved Oxygen

Dissolved oxygen values were always near saturation in the incoming waters. Actual velocities in the pipes varied from 0.5 to 1.0 fps., according to the flows, size of pipe and amount of tuberculation. Alkalinity differences reflect the lime dosages which were fed as saturated lime solutions. Stock lime solution was open to the atmosphere for approximately seven days before the solution was freshly made. Commercial grades of sodium hexametaphosphate and sodium pyrophosphate (tetra anhydrous) were made up every three days.

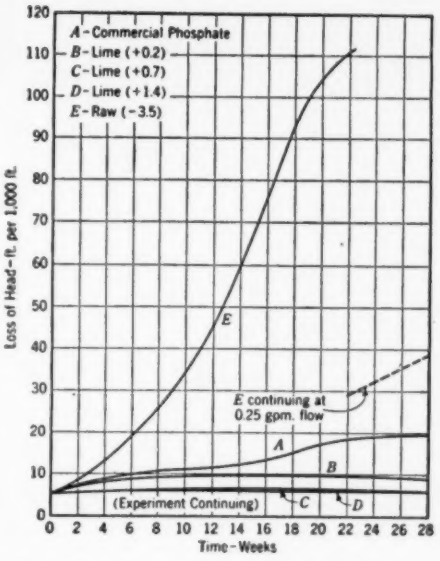

A - Commercial Phosphate
B - Lime (+0.2)
C - Lime (+0.7)
D - Lime (+1.4)
E - Raw (-3.5)
E continuing at 0.25 gpm. flow
(Experiment Continuing)
Loss of Head - ft. per 1,000 ft.
Time - Weeks

Fig. 6. Head Losses With Hetch Hetchy Water in ½-in. Pipe

TABLE II
Partial Data Summary—Average Values

Line	Loss in D.O. ppm.	pH	Alkalinity ppm. as $CaCO_3$	Temperature °F.	Ca ppm.
Crystal Springs Water—May 14, 1941					
A*	0.3	6.1	25	64	19
B*	0.3	7.7	73	64	19
C†	0.4	9.0	86	64	27
D‡	0.3	9.1	84	64	28
E	0.4	7.7	73	64	19
Crystal Springs Water—Mar. 19, 1946					
A*	0.4	7.6	57	66	18
B*	0.4	7.6	57	66	18
C‡	0.3	8.7	64	66	21
D‡	0.3	9.1	70	66	23
E	0.4	7.6	57	66	18
Hetch Hetchy Water—Apr. 22, 1946					
A*	0.4	7.1	10	59	4.0
B‡	0.2	9.5	18	59	7.0
C‡	0.1	9.8	26	59	10.0
D‡	0.1	10.2	36	59	15.0
E	0.5	7.0	10	59	4.0

*Lines receiving phosphate treatment (1 ppm.).
†Lines receiving phosphate and lime treatment.
‡Lines receiving lime treatment.

Temperature

The average water temperature in the Hetch Hetchy lines was 59° F., with a range between 57 and 68° F. Temperatures varied between 58 and 69° F. on the early Crystal Springs experiment, with an average of 64° F. The Crystal Springs experiments of 1946 ran between 55 and 70° F., with an average of 66° F. The pH values of the raw and lime-treated waters ranged from 7.0 to 10.2, and the pH values of the phosphate-treated waters ranged from 6.1 to 9.0. Computed carbon dioxide values, using Tillman's formula:

$$\log CO_2 = 6.2874 - pH + \log HCO_3 \text{ (as } CaCO_3\text{)}$$

varied between 0.01 and 2.8 ppm. in the raw and lime-treated waters and between 1.5 and 39.0 ppm. in the phosphate-treated waters. Chemical feed rates for the various feeders varied from 3.8 to 19.4 ml. per minute. Lime and sulfuric acid were used to make pH adjustments. A dosage of 1 ppm. was used in all phosphate treatments.

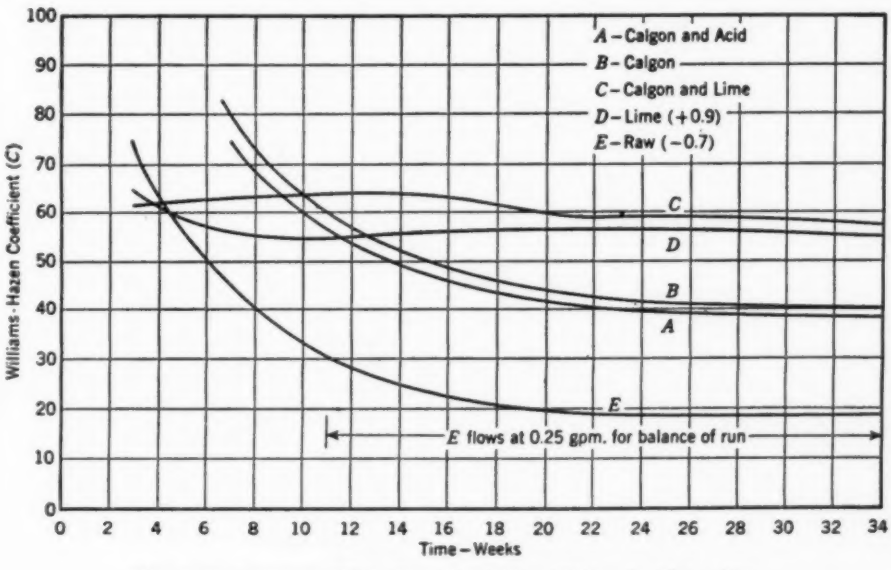

A - Calgon and Acid
B - Calgon
C - Calgon and Lime
D - Lime (+0.9)
E - Raw (-0.7)
E flows at 0.25 gpm. for balance of run
Williams - Hazen Coefficient (C)
Time - Weeks

Fig. 7. C Decrease With Crystal Springs Water in ⅜-in. Pipe

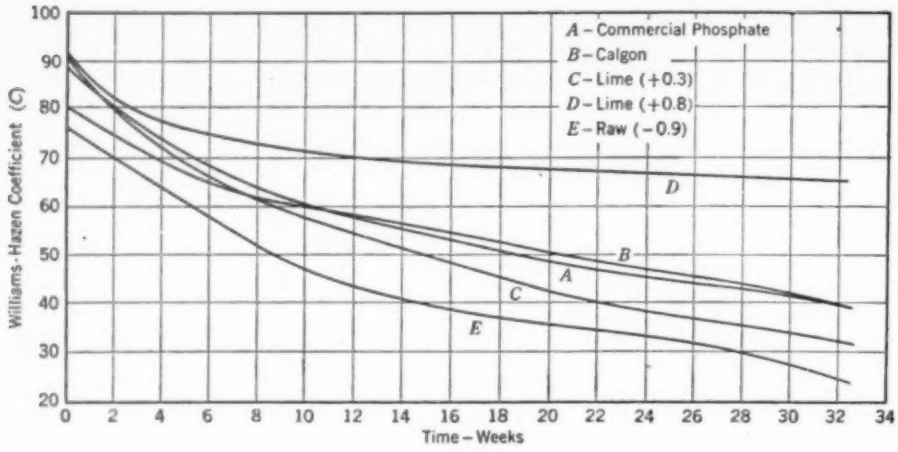


Fig. 8. C Decrease With Crystal Springs Water in ½-in. Pipe

Some interruptions occurred during the long runs, but all were minor and had little effect upon the results. The data obtained from the 1946 Crystal Springs test indicate a lower rate of corrosion in the early stages than was anticipated. This condition may be due to: (1) differences in pipe material, (2) inhibition of the metal by use of the acid cleaning material or (3) deposit or protective film due to cleaning or matter in the incoming water. Head losses with time as the experiment continues will indicate the nature of the variation. The time interval allowed for attainment of stability of the alkalinity relationship is small, varying between 20 seconds at the start of the run to 10 minutes when the head has built up and the mixing chambers are full. After this interval of mixing and reaction, the water enters the 50-ft. lines and flows through in 30 to 50 seconds, depending on the size of lines, amount of corrosion products and flow.

Microscopic Studies

The Crystal Springs water was chlorinated some distance before the experimental layout. No residual chlorine was detected in the raw water entering the corrosion lines. The Hetch Hetchy supply was taken from the raw water at Tesla Portal chlorination station before treatment. This supply had not been previously chlorinated. Microscopic examinations were made on material taken from the tanks, tubes and effluent containers in each of the experiments. In the Hetch Hetchy samples, a growth of the iron bacteria *Leptothrix* was identified in the storage tanks supplying the station. Growths of these bacteria occurred in the head boxes supplying the five lines. A thin matrix, containing diatoms, algae, organic and inorganic debris, and filamentous forms, was observed in the rubber connecting tubes. The lines were flushed several times and the residue examined. No active slime or filamentous growths could be observed.

Examinations of the Crystal Springs water in the corrosion apparatus revealed only organic and inorganic debris, algae, diatoms and protozoa. No active growths were observed in the tubes, boxes or containers. It cannot be stated definitely what effect organic growths had on the observed head losses; in these experiments, however, it is considered negligible, compared to the chemical action of the water. The role of bacteria and organic growth offers a field for further experimental work. Dye tests were made on the Hetch Hetchy experiment after 22 weeks of service and actual velocities through the lines were determined. These values, taken with those for the calibrated flow, were used to compute the effective pipe areas.

The decrease in effective area in line *A* was 10 per cent; in *B*, 14 per cent; *C*, 10 per cent; *D*, 5 per cent; and *E*, 25 per cent. It was noted that line *A*, which showed a reduction in area of only 10 per cent, had a head loss equal to 18 ft. per 1,000 ft., whereas *B*, with a reduction of 14 per cent, had a head loss equal to 9 ft. per 1,000 ft. This discrepancy may be explained by the physical character of the tuberculation. In the phosphate-treated lines, the rust deposits were continuous, flocculent and powder-like; the surfaces offered more resistance to flow than the deposits in the lime-treated lines, which were irregularly shaped and quite hard.

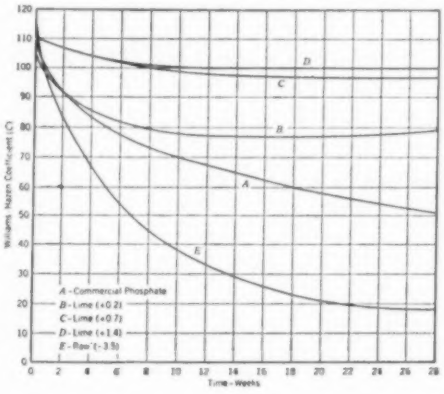


Fig. 9. C Decrease With Hetch Hetchy Water in ½-in. Pipe

The amount of fixed residue obtained from two sets of samples, after flushing the lines, varied with the friction head loss. The decrease in dissolved oxygen values, as shown in the partial data summary of Table II, was the highest in the raw water lines, averaging about 0.4 ppm. The phosphate-treated lines showed about 0.3 ppm. loss of dissolved oxygen. The decrease was lowest in the lime-treated waters. The more positive the saturation index number, the less the drop in dissolved oxygen.

Observations

On the basis of these data, the measurement of head losses directly reflects the aggressiveness or corrosive character of the raw and treated water. The following observations were made:

1. The decrease in the value of the flow coefficient (*C*) with time compares favorably with Langelier's saturation index.

2. The rate of tuberculation, using 1 ppm. of sodium hexametaphosphate at pH 6.1 and pH 7.7, is the same.

3. Sodium pyrophosphate and sodium hexametaphosphate in concentrations of 1 ppm. gave comparable protection as corrosion inhibitors.

4. Maintenance of a positive saturation index of +0.7 would give a high degree of protection. The large scale treatment could doubtless be reduced in Hetch Hetchy and increased slightly in Crystal Springs water.

5. Lime treatment to a saturation index of +1.4 in Hetch Hetchy water gave little added protection and would not be warranted on a large scale treatment basis.

Acknowledgment

The help of the members of the Purification Div. of the San Francisco Water Dept. is gratefully acknowledged.

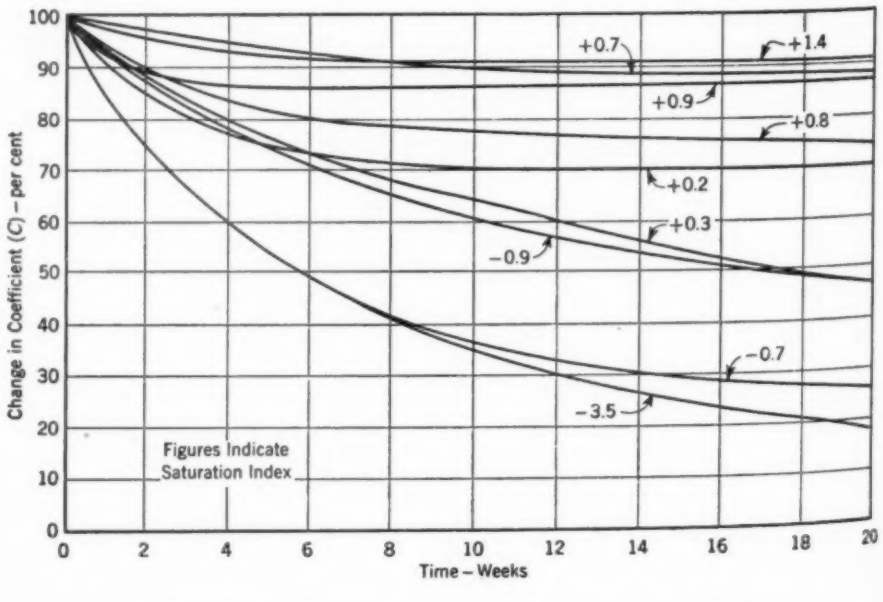


Fig. 10. Correlation of Saturation Index With Percentage of C Decrease

MANGANESE REMOVAL BY BREAK-POINT CHLORINATION

Experiences at Montebello Filters, Baltimore, Md.

By S. E. EDWARDS and G. B. McCALL
Montebello Filters, Baltimore, Md.

THE excessive presence of manganese in the raw water at Montebello Filters, Baltimore, Md., is a seasonal condition occurring from July through October. The usual procedure to cope with this condition is to substitute ferrous sulphate and lime as a coagulant (instead of alum) with a resultant pH of 9.0 for the coagulated water. Because of the inability to obtain satisfactory shipments of ferrous sulphate in 1943, it was imperative to find another method of manganese removal, so that the quality of water to the consumer would be unimpaired.

This problem of manganese removal had been recognized elsewhere. Erickson and Veatch[1] reported the use of chlorination, aeration, and a contact bed before filtration to remove manganese. Thirty-five per cent of raw water manganese was removed by the contact beds, 15 per cent in the settling basin and 45 per cent on the final sand filters, making a total removal of 95 per cent. Zapffe[2] passed water upward through pyrolusite (containing 70 per cent MnO_2) and sprayed the overflow on coke beds. Here the manganous hydroxide formed by catalysis is, in the presence of excess air, or oxygen, converted to stable manganic hydroxide and manganese dioxide. Montebello Filters does not have aeration or contact beds but by the use of chlorine as an oxidizer and the sand filters as a contact bed we assumed that the manganese could be removed. The basis for this assumption was derived from the experience of removing a small quantity of manganese from the water in the winter of 1944.

Early 1944 Experience Pointed the Way

During January, 1944, the daily average applied chlorine dose was 1.57 ppm. and the residual chlorine in the filter effluent was 0.31 ppm. In order to conserve chlorine, the applied dose was reduced to 0.94 ppm. in February and 0.78 ppm. in March. Although the chlorine residual in the filter effluent for February and March corresponded to that of January, the time required to obtain this residual reading with O-tolidine was 10 minutes instead of an instantaneous reading as in January. The explanation was found in the fact that the reduction of the chlorine dose below 1.00 ppm. permitted manganese which was then present in the raw water to pass the filters and appear in the filtered water to the extent of 0.10 ppm.

To ascertain the reason for the increased time required to obtain the chlorine residual and the presence of manganese in the filtered water, O-Tolidine-Arsenite[3] tests were conducted. These tests showed the residual to be 0.05 ppm. free chlorine and 0.25 ppm. chloramines. The results of these tests indicated that an increase in applied chlorine was necessary to obtain a true free chlorine residual.

The applied chlorine, therefore, was increased gradually from 0.8 ppm. to 1.8 ppm. This caused a decrease at first and then an increase in the chlorine residual, thus indicating the break-point had been reached. This fact was confirmed by the presence of 0.30 ppm. free chlorine and only 0.04 ppm. chloramines in the filtered water. We found the increase in the free chlorine residual was accompanied by a reduction of the manganese in the filtered water to zero. The elimination in March of this small quantity of manganese by the use of break-point chlorination made it seem logical that the larger quantities encountered during August, September and October each year could also be eliminated by heavy chlorination.

The Manganese Battle Starts in July

The manganese in the raw water began to increase on July 10, 1944, and continued until Oct. 21, 1944, at which time a maximum of 1.75 ppm. was recorded. The control procedure was to apply sufficient chlorine to maintain a true free chlorine residual of 0.4 ppm. to 0.5 ppm. at the effluent of the filters. On Sept. 27, 1944, the chlorine residual at the filter effluent dropped below 0.4 ppm. and by October 13, 1944, reached 0.19 ppm., even though the applied chlorine dose was 2.6 ppm. The effect of the low chlorine residual was to permit an increase in the manganese in the filtered water from 0.0 ppm. to 0.15 ppm. It was impossible to apply additional chlorine because we had reached the limit of our capacity, and our chlorine shipments were delayed.

During the next twenty-three days, the critical manganese period, it was necessary to use the ferrous sulphate and lime treatment for the manganese removal. This critical manganese period occurred at the time of "turnover" of the water in the impounding reservoir. The applied chlorine was 2.25 ppm. and the chlorine residual in the filter effluent was 0.45 ppm.—of this, only 0.10 ppm. was free chlorine and 0.35 ppm. was chloramines. Because of this change in ratio of free chlorine to chloramines during the "critical manganese period," objectionable tastes were present due to algae. This condition was corrected by the use of activated carbon. By November 10, 1944 the manganese in the raw water had decreased to 0.01 ppm., therefore, at this time the ferrous sulphate and lime treatment was terminated and the alum treatment restored.

1945 Procedure Completely Successful

This experience of 1944 definitely proved our assumption that if sufficient chlorine were applied the manganese could be removed. It was, therefore, decided to continue the experiment during 1945. The manganese in the raw water, as in previous years, began to increase July 10, 1945, continuing until a maximum of 1.05 ppm. was reached on October 20, 1945. In addition to the regular chlorine equipment, three Rotameters—two of 2,000 pounds per day capacity and one of 6,000 pounds per day capacity—enabled us to apply 4.5 ppm. of chlorine. This was sufficient chlorine to maintain a true chlorine residual of 0.4 ppm. in the filter effluent, and to give the consumer a water which was free of manganese for the entire year. The chlorine-manganese relation for 1945 is shown in the accompanying graph.

Tests were made of the effluents of the settling basin, the filters, and the clear water reservoir to ascertain the reduction of manganese through the plant. The results for the year 1945 were 25 per cent raw water manganese removal in the mixing and settling basins and 75 per cent removal by the sand filters, giving a total removal of 100 per cent. Some of the actual removal was due to the catalysis caused by the manganese coated sand grains.

To prove catalysis was responsible for some of the manganese removal an experiment was conducted in a small glass filter. This glass filter was prepared by filling a glass tube six feet long and two and a half inches in diameter with six inches of gravel and eighteen inches of manganese coated sand from a plant filter. Raw water (without any treatment whatsoever) containing 0.5 ppm. manganese was run through this filter at a rate of two gallons per square foot per minute. This test showed complete removal of the raw water manganese for twenty-four to thirty-six hours after which time manganese was present in the effluent. This demonstrated that catalytic action of the sand had ceased. The filter was then turned off and a strong chlorine solution applied to the sand. Following this, the sand was thoroughly washed with tap water to remove the chlorine. Raw water was again run through this filter and the effluent was free of manganese for another 24 to 36 hours. The chlorine had thus reactivated the sand so that catalysis could be resumed.

Effect on Tastes and Bacterial Quality

Accompanying the manganese removal by break-point chlorination was a decrease in bacteria and a most gratifying decline in taste complaints. The 1940 bacteriological record for the plant effluent of the presumptive lactose tubes was 1.1 per cent positive in the 1 ml. portions and 13.0 per cent positive in the 10 ml. portions, whereas the 1945 record for the presumptive lactose tubes was 0.0 per cent positive in the 1 ml. portions and 0.3 per cent in the 10 ml. portions. The confirmative lactose tests for 1940 were 0.3 per cent in the 1 ml. portions and 0.9 per cent in the 10 ml. portions while those of 1945 were 0.0 per cent in both the 1 ml. and 10 ml. portions. These results are shown in Table I. The bacteriological quality of the raw water for 1945 was poorer than for 1940. Therefore, this improvement in bacteriological results must be attributed entirely to the increase of applied chlorine and the fact that a true free chlorine residual could be maintained.

TABLE I

Bacteriological Record Plant Effluent

	Presumptive Test % Positive		Confirmative Test % Positive	
Year	1 ml.	10 ml.	1 ml.	10 ml.
1940.....	1.1	13.0	0.3	0.9
1941.....	0.4	10.2	0.0	0.2
1942.....	2.5	19.0	0.0	0.1
1943.....	0.6	8.5	0.0	0.1
1944.....	1.0	7.5	0.0	0.0
1945.....	0.0	0.3	0.0	0.0

The use of chlorine residual above 0.25 ppm. had heretofore been considered unwise because of objectionable taste. This fact has been disproved at Montebello Filters where chlorine residuals as high as 0.60 ppm. have been recorded without any com-

plaints from the consumer. The increase in chlorine residual from an average of 0.17 ppm. in 1940 to an average of 0.37 ppm. in 1945 has decreased correspondingly the complaints of objectionable tastes. (See Table II.)

TABLE II

Year	Number of Taste Complaints	Avg. Residual Chlorine ppm.
1940	516	0.17
1941	133	0.19
1942	60	0.22
1943	28	0.26
1944	30	0.36
1945	0	0.37

A Comparison of Costs

The chemical cost for the removal of manganese from the raw water by break-point chlorination was also considered. Since the water quality in 1939 was more nearly that of 1945 these years were chosen for comparing costs. The cost of chemicals used in September and October 1939 was compared with chemical costs for the same months of 1945. As stated above, the treatment formerly employed at the Montebello Filters for manganese removal was the use of ferrous sulphate and lime. Furthermore, since September and October are the months of excessive manganese it was decided that better cost comparison could be made by using these months as a basis. It was found that coagulation costs were comparable for either alum or ferrous sulphate and lime when local prices for these chemicals were used. The difference in cost of the two methods lay in the fact that activated carbon was necessary with the ferrous sulphate and lime treatment but not with the break-point chlorination. As shown in table 3 an average of 6.51 pounds of chlorine per mil. gal. and 16.64 pounds of activated carbon per mil. gal. were used in 1939, while 26.60 pounds of chlorine per mil. gal. and 0.0 pounds of carbon were used in 1945. Using a price of 4 cents per pound for carbon and 2.4 cents per pound for chlorine made the cost of carbon and chlorine 82 cents per mil. gal. in 1939. The cost of break-point chlorination in 1945 was only 64 cents per mil. gal. This was a difference of 18 cents per mil. gal., a saving of 22 per cent by using the break-point chlorination method for manganese removal.

TABLE III

MONTH	Raw Water Manganese p.p.m. 1939	Raw Water Manganese p.p.m. 1945	Chemicals—Pounds Per Million Gallons: Alum 1939	Alum 1945	Ferrous Sulphate 1939	Ferrous Sulphate 1945	Lime 1939	Lime 1945	Chlorine 1939	Chlorine 1945	Carbon 1939	Carbon 1945
September	0.26 to 0.67	0.22 to 0.45	0	6.34	9.67	0	9.26	4.50	6.17	24.60	14.93	0.00
October	0.28 to 1.05	0.23 to 1.05	0	6.26	10.67	0	9.17	5.34	6.84	28.60	18.35	0.00
Average	...	...	0	6.30	10.17	0	9.22	4.92	6.51	26.60	16.64	0.00

Conclusions

In summary, the following conclusions have been reached at Montebello Filters:

1. A water whose residual is chiefly chloramines requires a longer time to obtain an O-tolidine reading than one whose residual is free chlorine.

2. Increasing the applied chlorine past the break-point gives a true free chlorine residual.

3. This free chlorine has the following effects: Elimination of manganese, improved bacteriological record, and a decline in taste complaints.

4. Catalysis of the manganese coated sand in the filters is responsible in part for the complete manganese removal.

5. Break-point chlorination is more economical than the ferrous sulphate-lime treatment and far simpler.

6. Break-point chlorination eliminates the use of activated carbon.

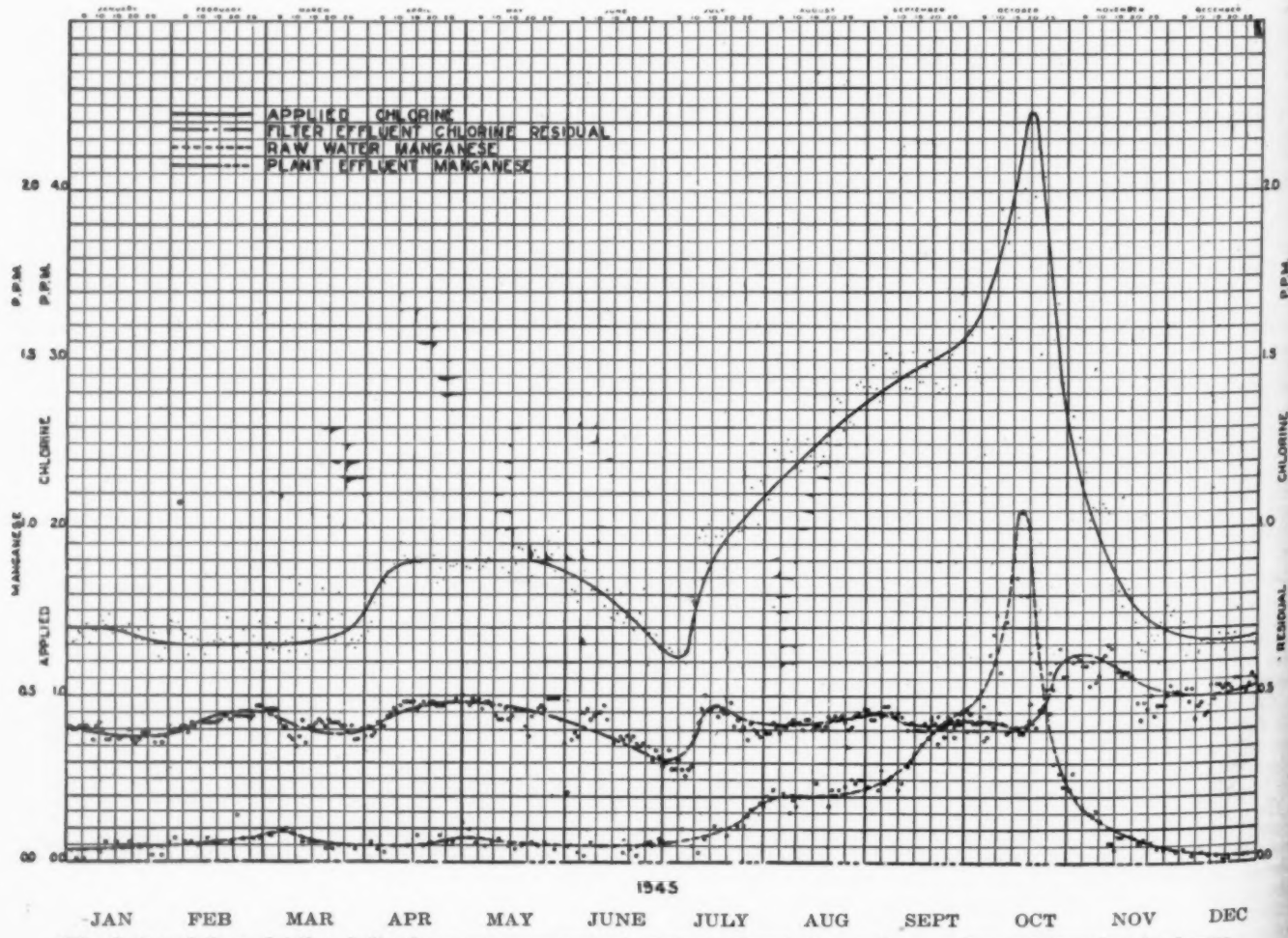
Therefore, we have found when break-point chlorination with a free chlorine residual of 0.40 ppm. is maintained in the filter effluent, the raw water manganese can be entirely removed by the Montebello Filters.

References

1. Veatch & Erickson, *J.A.W.W.A.*, 29:12, 1896 (Dec., 1937).

2. Zapffe, *J.A.W.W.A.*, 25:5, 655 (May, 1933).

3. Hallinan, *J. A. W. W. A.*, 36:3, 296 (March, 1944).



(The dash and three-dot line, indicating manganese content of plant effluent, lies on the zero line and therefore is obscure on the graph.)

Record Graph Showing Relationship of Chlorine Applied, Residual Chlorine and Effectiveness of Manganese Oxidation and Removal.

P.P.M.
CHLORINE
RESIDUAL

PART 7

SEWAGE TREATMENT

WATER & SEWAGE WORKS

REFERENCE & DATA SECTION

1947

J. C. FITZGERALD

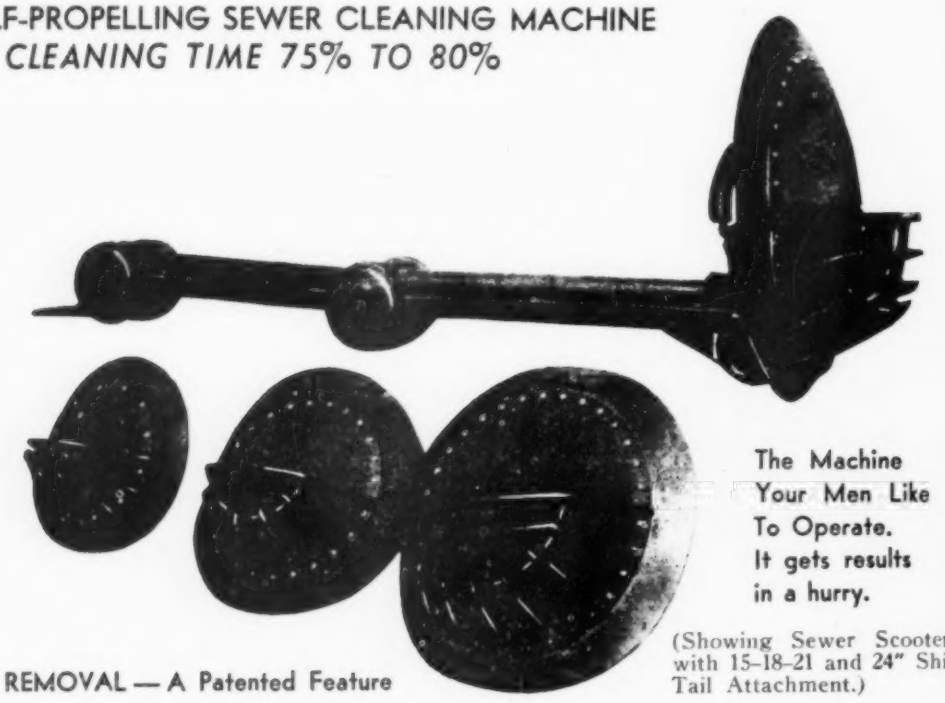
Manufacturer of SEWER SCOOTER

Post Office Box 289, CORAL GABLES 34, FLORIDA

THE ONLY 100% SELF-PROPELLING SEWER CLEANING MACHINE
REDUCES CLEANING TIME 75% TO 80%

No Preliminary Work Required

Sewage Furnishes the Operating Power



The Machine Your Men Like To Operate. It gets results in a hurry.

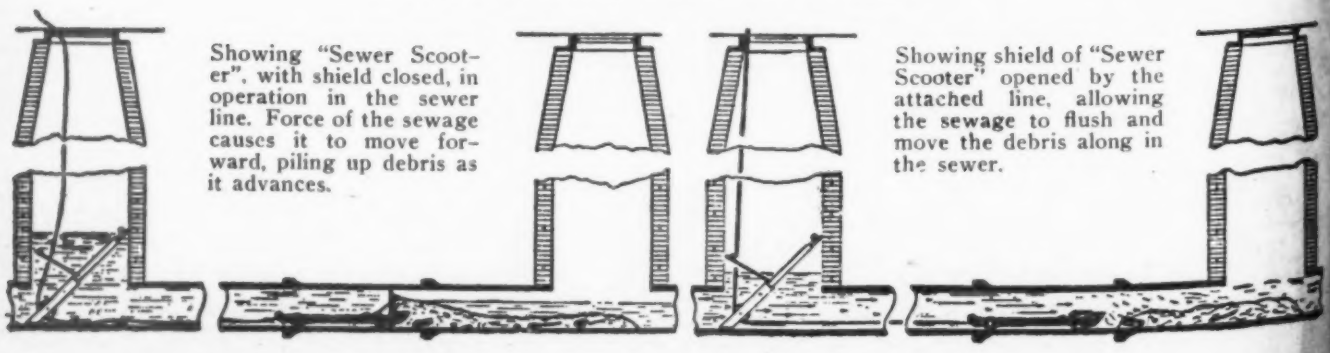
(Showing Sewer Scooter Model with 15–18–21 and 24" Shields and Tail Attachment.)

COLLAPSIBLE FOR EASY REMOVAL — A Patented Feature

The SEWER SCOOTER is simple and economical to operate. It is a self propelling device that has all the advantages of the flush tank, but will move along and completely clean the line as the debris is moved ahead. The snugly fitting, collapsible rubber-edged shield scrapes the inside of the pipe clean as it moves along; the Shield is collapsed to flush the debris ahead, but when it encounters objects too heavy and solid to be moved by flushing it is used as a ram to clear the line. Until you see it operate you will not believe what it will move.

It is designed to pass fixed obstructions that extend into the sewer, such as plumbers' taps and crushed pipe.
Because it will by-pass obstructions it will pass through places where drag buckets will not go.
It cleans inverted siphons if they are constructed with fittings not over 22½ degrees.
Built in sizes to fit into sewer lines 8 inch to 36 inch. Other sizes and shapes other than round are made to order.
Reduce your operating expenses as so many other cities have done.
Write to us for details of its operation.

Showing sand taken from a 21" sewer 320 feet long. The time required was three hours from start to finish.



Showing "Sewer Scooter", with shield closed, in operation in the sewer line. Force of the sewage causes it to move forward, piling up debris as it advances.

Showing shield of "Sewer Scooter" opened by the attached line, allowing the sewage to flush and move the debris along in the sewer.

odel
and

ad-
The
l is
t is

pe.

ler.

MODERN FINANCING OF SEWAGE WORKS*

FINANCING sewage works by revenue bonds secured by service charges is comparatively new. It is, however, a form of financing which promises wide acceptance because it is equitable and economically sound. Here are reasons why:

Sewer rental charges are small:

When billed on a monthly or quarterly basis, charges are accepted without question after the first few billings;

Delinquencies are, for the most part, negligible;

Purchasers of revenue bonds have good security.

In this booklet revenue bonds are considered as a form of municipal bond issued to construct or improve revenue-producing works when the payment of such bonds depends entirely upon the revenue from the utilities. These include sewerage systems, sewage-disposal and water works.

Although the full faith and credit of the political subdivision is not directly pledged as security for revenue bonds, the financial standing and debt history of a municipality have an important bearing upon the value of the bonds. Revenue bonds should be considered as a sound means whereby progressive municipalities may build needed improvements without disrupting other budgeted requirements and without adding anything to their general debt or tax burdens.

State and Municipal Legislation

Legislation permitting revenue bond financing of sewage works exists in 33 states. Because some of these laws were passed as emergency measures, amendments may be necessary to make the full benefits available. If enabling legislation is not adequate or is of temporary nature, it should be amended. An enabling act should provide that the department of the municipality responsible for building and operating public works may proceed with a required sewerage project upon the approval of the common council or board of trustees, and after a satisfactory ordinance has been drawn. [If the reader is interested in a typical Revenue Bond Ordinance a copy will be supplied upon request. The length of the ordinance was too great for reproduction here.—

In some cities home rule charters may have to be revised to permit taking advantage of the broader scope of state legislation.

It is important that any change in state legislation or in municipal charters be suggested only after careful study of the state constitution and existing laws.

Kinds of Financing

The problem of financing sewerage facilities is of major importance to municipalities. Although most of the discussion in this booklet concerns the revenue bond method, other means are touched upon, since some cities may find them desirable. There are four principal methods for financing sewerage facilities:

1. General Tax Obligation Bonds;
2. Special Assessments;
3. Service Charge and Revenue Bonds;
4. Combination Method.

General Tax Obligation Bonds

The most used method of financing municipal improvements has been by ad valorem tax upon all real property within the municipality. Bonds have then been issued upon the basis that the improvement becomes a general obligation of the incorporated municipality. This method considers the improvement of general benefit to all property, and the tax paid by an owner to be in direct proportion to the amount of property he possesses without recognizing the utility feature of water works and sewerage.

In times of stress this method may not permit the city or town to construct or extend sewerage facilities that are vitally needed. When an improvement is most needed, the municipality may have a bonded indebtedness approximating the state constitutional or statutory limitation.

Special Assessments

The special assessment method of financing is based upon the taxing of property in proportion to the benefits bestowed. The property owner may pay his share of the cost of the undertaking outright or in a stated number of installments, usually ten. When an installment is due he receives a notice. He is expected to pay promptly what is due plus interest on the unpaid balance.

Special assessment bonds may or may not be issued, depending upon the municipality's ability to carry the cost out of other funds, or the willingness of the contractor to take assessment warrants in at least part payment.

This method of financing also leaves out of consideration payment in proportion to service rendered.

Service Charge Revenue Bonds

The revenue bond method of financing public improvements does not add to the general debt. Sewer rentals which are security for the bonds provide a means of charging the person receiving the service and in proportion to use.

The most practical method of sewer rental is a charge based on water consumption. A sewer rental schedule may be set up by ordinance for various classes of users, and users may be charged a fixed percentage of the water bill.

If for any reason it is not practicable to use water meter readings, rates can easily be adjusted to a flat rate or connection basis, depending upon the kind and size of premises occupied and the number of service connections. In any case, individual demands should be carefully studied and classified and the rates fixed accordingly. [A typical rate ordinance is given at the end of this chapter.—Editor.]

The monthly or quarterly per capita charge for the entire cost of a new sewage works plus its operating cost is generally quite small, and therefore no hardship even on the very low income group. The minimum rate at Oak Park, Illinois, for example, is $1.50 per quarter, or less than the cost of a daily paper. Of the 11,500 accounts on Oak Park's books, approximately 2,600 pay the minimum bill, and 3,600 pay the next higher rate.

Combination Financing

Sewer rentals may be charged even though the project may not be financed with revenue bonds. In some cases sewer service charges have been used merely to care for maintenance and operation. The equity of charging the user a proportion of the construction cost, however, is well recognized.

Also, sewer rentals may be used to retire general tax obligation bonds used for sewer construction. Furthermore, in ordinances establishing sewer rentals for operation and maintenance, it is usually provided that any surplus accruing from the rental collections shall be applied to the construction cost.

Where extensions or construction of waterworks are being considered with sewerage improvements, it is often advantageous to finance with combined waterworks and sewerage revenue bonds.

Sewer Rental Experience

Some fear has been expressed regarding possible delinquencies in sewer rental collections. Those who anticipate this difficulty will find that their fears have little foundation in practice. Examination of the sewer rental experience table reproduced herewith shows the small percentage of delinquencies.

In financing sewage works by the revenue bond method, questions may arise regarding the equity of the rates for sewer rentals. While the rate depends largely upon service actually used, it must be recognized that there is a definite benefit to property whether the sewer is connected or not.

An accepted principle of making a ready-to-serve or availability charge can be applied to the establishment of sewer rental rates. This principle may also be extended to cover the cost of storm sewers or, if a combined system is built, a share of the added cost.

Various methods have been used for establishing such charges. In some cases the sewer rental charge has been made to finance the construction of the treatment plant, and the cost of the collection system has been met by an entirely different method, usually some form of direct taxation or special assessment.

Where sewer rentals are to be applied to construction of both treatment plant and collection system, some municipalities have established a small ready-to-serve charge. Another and fairly general practice is to make a substantial charge for initial connection to the sewer.

(See Experience Record at end of article.)

*The material under this heading has for the most part been taken from a brochure published by the Portland Cement Association, copies of which are available upon request.

General Procedure

Carrying a sewerage project through under any kind of financing involves a number of important steps. These do not necessarily follow in order, and some of them may be taken concurrently. The principal steps are:

Make a preliminary sanitary survey;
Start a campaign to get public support;
Select a competent sanitary engineer;
Select a recognized bond attorney to prepare the bond ordinance and bond certificates;
Publish the bond ordinance;
Advertise the bond issue;
Prepare the rate schedule and publish the rate ordinance;
Prepare forms for billing the user.

Preliminary Survey

Before the need for new sewerage facilities is determined, it is desirable to have some public sentiment favorable to such improvement. The water supply may have become contaminated, and householders will start to complain of disagreeable tastes and odors. Public bathing beaches may have to be closed. Marine life may have been endangered by pollution. State health departments may have determined that a nuisance exists. All these conditions may indicate new sewage works are required, but the actual need should be established by a preliminary survey. Such a survey need not be comprehensive, but enough facts should be gathered to justify the improvement.

Securing Public Approval

Now that the municipality has decided to proceed with the construction of sanitary facilities and it has been determined that there are no legal barriers, the next logical step is to enlist widespread public support. Even though bonds may be issued without referring the matter to popular vote, the public should be informed on the urgency of the proposed construction and the entire plan of procedure.

Many city councils prefer a referendum so that there will be official record of the public's approval.

When, and if, the bond issue is to be put to a vote of the people, it is essential that the voters have full knowledge of the necessity of the project, and that they be given enough construction and operation cost information to impress them with the fact that for an exceedingly small charge they are being given an indispensable service. Many bond issues have been lost because voters gained erroneous impressions from unreliable sources.

Public approval of the proposed project should be sought through a general educational campaign, which should point out:

That public health is endangered by continuation of existing conditions;

That the city may be (or has been) sued because of stream pollution and that the taxpayers will have to pay for the resulting damage;

That sound financing methods will be followed;
That costs will be reasonable;
That engineering advice and construction supervision will be competent;
That charges will be small and on the basis of use;
And further, that there will be no added tax burdens.

The whole educational program should be placed in the hands of a competent central committee. The following outline suggests major steps in an educational campaign:

A. Establish central committee
   1. Headquarters
   2. Volunteers
   3. Appoint publicity director
B. Report on investigations
   1. Engineer's report
   2. Financing methods (advice obtained from bond attorneys)
   3. Comparable conditions in other cities
      How remedied?
C. Publicity
   1. Newspaper articles
      Full details given to press; cooperation obtained in interest of public welfare
   2. Advertisements—if election to be held, present final conclusive arguments immediately preceding election day
   3. Booklets and pamphlets —simple, direct statements
D. Canvassing
   1. Individual calls by volunteers
   2. Endorsements by prominent citizens.
E. Local organizations
   1. Obtain support of local groups
      Business
      Professional
      Chambers of commerce
      Women's organizations
      Civic clubs
      Schools, etc.
F. Lectures and radio talks
   1. By city officials
      Engineers
      Attorneys
      Volunteer citizens
G. Displays
   1. Posters in store windows
   2. Posters in homes

Selecting the Consulting Sanitary Engineer

The job of building modern sewage works requires highly specialized ability, and should be entrusted only to a competent sanitary engineer.

Although the sanitary engineer will know what facts he will have to gather, others not technically trained will be interested in a brief picture of the scope of his necessary investigations, which are as follows:

Source and quality of water supply.

Stream-gage measurements, particularly low-water and flood stages, if the water supply is taken from a river or the sewage effluent is to be diverted to a river or stream.

Population characteristics, with particular reference to population stability, proportions in various income groups, whether population is increasing or decreasing, etc.

Land use characteristics of the area. It should be known what proportion of the area to be served is industrial; how much is commercial and how much residential, with these areas located with respect to municipal corporate limits or sanitary district limits; and the recreational facilities of the community, etc.

Physical characteristics of the area. Obviously, a physical survey will have to be made to determine where the plant is to be built to take full advantage of gravity flow of sewage, to determine if any pumping will be necessary, and to solve other problems concerned with actual design.

The number of water connections in the area to be served by sewerage facilities, and the probabilities of increase. Adequacy of existing water supply and probable reasonable increase also will be established. It should certainly be known how many sewer connections exist and whether the connections are industrial, commercial or residential.

Method of garbage collection and disposal.

These are a few of the many important things the sanitary engineer will investigate.

Selecting Bond Attorney

A recognized bond attorney should be consulted at the outset. In cooperation with the city attorney, the bond specialist will prepare and approve the necessary ordinances and form of bond proposal.

This procedure not only protects the city against legal faults, but it helps materially in selling the bonds. An opinion of a recognized bond attorney will be necessary before the bonds are delivered, but a preliminary opinion is desirable, as it obviates subsequent delay. Also, if bond purchasers know that all details have been handled or approved by bond specialists, the bonds will be regarded much more favorably.

Publishing Bond Ordinance

As soon as the bond attorney and the city attorney have drafted the bond ordinance, the city council should pass the ordinance and publish it. The way is then clear for financing the project.

Advertising Bond Issue

City officials will find helpful suggestions regarding the bond advertisement in a municipal circular issued by the Investment Bankers Association of America. These suggestions, embodied in Recommendation No. 19, are:

"19. SPECIAL REVENUE BONDS:

"Reference is made to a resolution adopted by the Board of Governors on May 11, 1937, that part of which outlining specifications is as follows:

" 'That advertisements or circulars describing revenue bonds shall clearly indicate the nature of the obligation.

" 'That the customary form of the ordinary municipal circular and advertisement be varied to prevent confusion in the mind of the casual or careless reader.

" 'That the type of obligation be clearly described in the caption, and with prominence consistent with that accorded to the name of the municipality.

" 'That priority of obligation, if any, be stated specifically.

" 'That the statement of assessed valuation, total debt, etc.

if included, be given a secondary rather than a primary position.

"'That in connection with such statement of assessed valuation, etc., a statement shall be made, and prominently displayed, to the effect that the assessed valuation reported is not subject to taxation for the payment of principal and interest on the bonds.'"

Bonds may be offered for sale as soon after the issue has been advertised as seems convenient or advisable. The services of some financial specialist may be secured to advise the city officials when the bonds may be most advantageously sold and in what amounts.

Establishing Rate Schedule

An equitable rate schedule is fundamental to successful financing of sewerage facilities by the revenue bond method. Obviously, then, care must be exercised in adjusting the schedule to the kind and amount of service rendered.

The recommendations of the sanitary engineer should be sought in establishing the rates. He will view the proposed schedule from the standpoint of existing earning capacity plus reasonable future increases. It cannot be emphasized too strongly that an adequate and equitable rate schedule will enhance the possibilities for advantageous sale of the bonds. An inadequate schedule may jeopardize the entire program. Raising deficient rates is far more difficult than lowering rates found to yield more revenue than is currently required.

Preparing Billing Forms

Municipalities have worked out ingenious methods of billing to meet their particular requirements. A simple statement showing separately the amounts charged for water and for sewerage service is generally preferred, however. Where possible, the billing and collection of sewerage charges can be made by the same staff and at the same time as the water bills. This has been done by several cities at almost no increase in collection costs.

It is especially desirable that bills be rendered monthly or quarterly. An annual charge for a new municipal service, however reasonable, may appear exorbitant to the payer.

Two single billing forms are reproduced on the next page.

Typical Sewer Rental Ordinance

AN ORDINANCE

FIXING THE RATES TO BE CHARGED BY THE CITY OF DAYTON, OHIO, TO THE OWNERS OF BENEFITED PROPERTY FOR THE USE OF ITS SANITARY SEWERAGE SYSTEM, OF PARTS SANITARY SEWERAGE SYSTEM AND TREATMENT WORKS.

WHEREAS, . . . THEREFORE,

BE IT ORDAINED BY THE COMMISSION OF THE CITY OF DAYTON:

Section 1. It is hereby determined and declared to be necessary and conducive to the protection of the public health, safety, welfare and convenience of the City of Dayton, Ohio, to levy and collect charges or rentals upon all lots, lands, and premises served by having connections with the sanitary sewerage system and by the sewage pumping, treatment and disposal works of said City, the proceeds of such charges or rentals so derived to be for the use of the sanitary sewerage system and the pumping, treatment and disposal works of said city, as hereinafter provided.

Section 2. (Defines "Sanitary Sewage" and "Industrial Wastes."—Editor).

Section 3. For the purposes as provided in Sections 1 and 8 hereof there is hereby levied and assessed upon each lot, parcel of land, building or premises having any sewer connection with the sanitary sewerage system of said city or otherwise discharging sewage, industrial wastes, water or other liquids, either directly or indirectly into the City sanitary sewerage systems, a sewerage service charge or rental payable as hereinafter provided, and in amount determinable as follows:

(a) For any lot, parcel of land, building or premises situated within the corporate limits of the City of Dayton, Ohio, and having any connection with the city sanitary sewerage system or otherwise discharging sanitary sewage, industrial wastes, water or other liquids, either directly or indirectly, into the City sanitary sewerage system, said charge or rental shall be based upon the quantity of water used thereon or therein as the same is measured by the City water meter there in use, and there shall be charged: for the first 3000 cubic feet of water, or part thereof, so used per quarter year, the sum of One Dollar ($1.00); for each thousand cubic feet of water used in excess of 3000 cubic feet and not exceeding 10,000 cubic feet, per quarter year, at the rate of Thirty Cents (30c) per 1000 cubic feet; for each thousand cubic feet of water in excess of 10,000 cubic feet and not in excess of 20,000 cubic feet, per quarter year, at the rate of Twenty-five Cents (25c) per 1000 cubic feet; for each thousand cubic feet of water in excess of 20,000 cubic feet and not in excess of 100,000 cubic feet per quarter year, at the rate of Twenty Cents (20c) per 1000 cubic feet; for each thousand cubic feet in excess of 100,000 cubic feet and not in excess of 500,000 cubic feet per quarter at the rate of Fifteen Cents (15c) per one thousand cubic feet; for each thousand cubic feet in excess of 500,000 cubic feet per quarter at the rate of ten cents (10c) per 1000 cubic feet; provided, that the minimum charge shall be One Dollar ($1.00) per quarter year or part thereof.

(b) For any lot, parcel of land, building or premises situated outside of the corporate limits of the City of Dayton, Ohio, and having any connection with the city sanitary sewerage system or otherwise discharging sanitary sewage, industrial wastes, water or other liquids, either driectly or indirectly, into the city sanitary sewerage system, said charge shall be based upon the quantity of water used thereon or therein as the same is measured by a water meter there in use which meter shall be to the approval of the Director of Water, and there shall be charged for the first 3000 cubic feet of water, or part thereof, so used per quarter year, the sum of One Dollar and Twenty-five cents ($1.25); for each thousand cubic feet of water used in excess of 3000 cubic feet and not exceeding 10,000 cubic feet, per quarter year, at the rate of Thirty-eight cents (38c) per thousand cubic feet; for each thousand cubic feet of water in excess of 10,000 cubic feet and not exceeding 20,000 cubic feet per quarter year at the rate of Thirty-one cents (31c) per thousand cubic feet; for each thousand cubic feet of water in excess of 20,000 cubic feet and not exceeding 100,000 cubic feet per quarter at the rate of twenty-five cents (25c) per thousand cubic feet; for each thousand cubic feet in excess of 100,000 cubic feet and not in excess of 500,000 cubic feet per quarter, at the rate of nineteen cents (19c) per thousand cubic feet; for each thousand cubic feet in excess of 500,000 cubic feet per quarter at the rate of thirteen cents (13c) per thousand cubic feet; provided that the minimum charge shall be One Dollar and Twenty-five cents ($1.25) per quarter year or part thereof.

(c) In the event a lot, parcel of land, building or premises discharging sanitary sewage, industrial waste, water or other liquids into the City sanitary sewerage system, either directly or indirectly, is not a user of water supplied by the Department of Water of said City and the water used thereon or therein is not measured by a city water meter, or by a meter acceptable to the Director of Water, then, in each such case the amount of water so used shall be otherwise measured or determined by the Director of Water in order to determine the sewer service charge or rental provided in this ordinance, or the owner or other interested party at his expense may install and maintain a meter acceptable to the Director of Water for said purpose.

(d) In case a lot, parcel of land, building or premises discharges industrial wastes, either directly or indirectly, into the City sanitary sewerage system, and the Director of Water finds that it is not practical to attempt to measure such wastes by meter, he shall measure such wastes in such manner and by such method as he may find practicable in the light of the conditions and attendant circumstances of the case, in order to determine the sewer service charge or rental, according to the corresponding rates per thousand cubic feet provided in this ordinance.

(e) A discount of five (5) per cent shall be allowed for prompt payment.

In addition to the charge or rental determined according to the rates specified herein a further charge of five (5) per cent of such amount so determined shall be added thereto in each case of failure to make prompt payment, and the total thus obtained shall be the sewerage service charge or rental in each such case.

("Prompt Payment" defined.—Editor.)

(f) The sewer service charge or rental provided in this ordinance shall be payable quarterly at the office of the Department of Water, and, at the option of the Director of Water may be made payable at the same time as water bills in the district in which the property is located are payable.

(g) (Exempts City, County, State, and Federal property except specified institutions.—Editor.)

Section 4. For any lot, land, building or premises from which connection is made with the City sanitary sewerage system or which begins to discharge sewage, any industrial waste, water or other liquids into the City sanitary sewerage system, either directly or indirectly, after this ordinance becomes effective, a charge shall be made pursuant to this ordinance, the same to be a

per diem pro rata amount based upon the minimum rate per quarter from the time such sewer connection is made, or such discharge into the City sewerage system, either directly or indirectly, is begun, until the next following quarter period, except should the measured service exceed the minimum charge the corresponding measured rate or rates shall be charged.

Section 5. The charge or rental levied and assessed by this ordinance shall be payable in four quarterly payments in each year, as provided in Section 3, paragraph (f), hereof, provided that the amount of the rental payable for any lot or premises at the first payment period after this ordinance becomes effective shall be determined on the basis of a per diem pro ratement or the minimum charge herein established beginning with the date this ordinance becomes effective, except that in those cases in which the metered or measured charge will exceed the minimum charge, the metered or measured charge shall be the basis.

Section 6. Each charge or rental levied by or pursuant to this ordinance is hereby made a lien upon the corresponding lot, land or premises served by a connection to the sanitary sewerage system of the City of Dayton, Ohio, and if the same is not paid within thirty (30) days after it shall be due and payable it shall be certified to the Auditor of Montgomery County, Ohio, who shall place the same on the tax duplicate of said county with the interest and penalties allowed by law and be collected as other taxes are collected.

Section 7. The charges or rentals levied pursuant to this ordinance shall be collected by the Department of Water, and the Director of said Department shall make and enforce such by-laws and regulations as may be deemed necessary for the safe, economical and efficient management and protection of the City sewerage system and the sewage pumping, treatment and disposal works, for the construction and use of house sewers and connections to the sewerage system, and for the regulation, collection, rebating and refunding such charges or rentals.

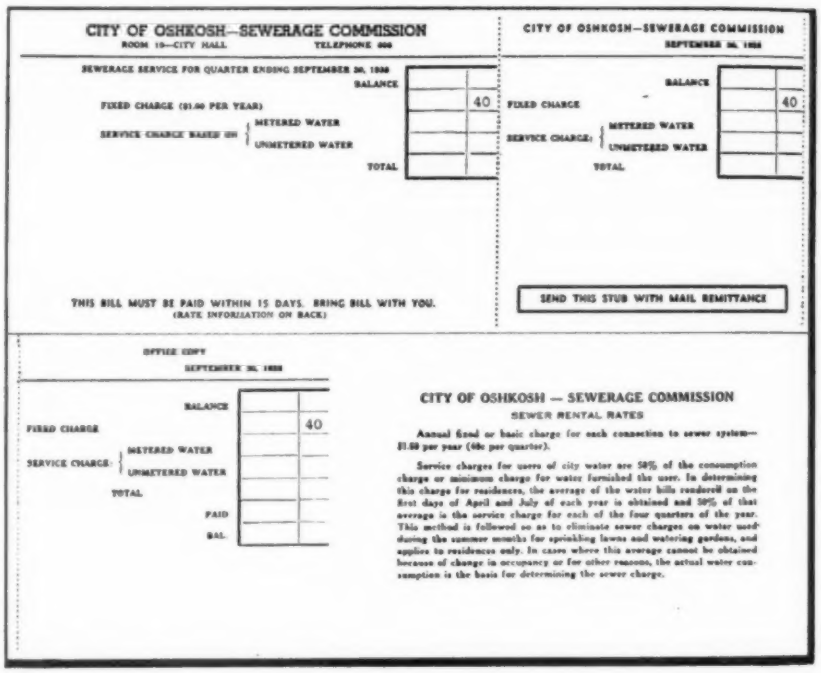
Section 8. The funds received from the collection of the charges or rentals authorized by this ordinance shall be deposited daily with the City Treasury and shall be accounted for and be known as the Sanitary Sewer Fund, and when appropriated by the City Commission, shall be available for the payment of the cost and expense of the management, maintenance and repair of the City sanitary sewerage system and the sewage pumping, treatment and disposal works, and any surplus in such fund shall be used for the payment of the interest on bonds issued and outstanding or which may be issued to provide funds with which to pay the City's portion of the cost of constructing such sanitary sewerage system, or part thereof, and such sewage pumping, treatment and disposal works and to retire such bonds when they mature, and/or for the enlargement or replacement of said sanitary sewerage system, pumping, treatment and disposal works, except that no part thereof shall be used for the extension of such sewerage system into unsewered areas.

Passed by the Commission December 28, 1927.

Typical Billing Forms

The billing side of the Oshkosh, Wisconsin, form at right is in three sections, the sewer rental rates being shown on the reverse side.

The billing form below is used by the City of Lebanon, Illinois



CITY OF OSHKOSH—SEWERAGE COMMISSION
ROOM 10—CITY HALL TELEPHONE 600

SEWERAGE SERVICE FOR QUARTER ENDING SEPTEMBER 30, 1930

BALANCE
FIXED CHARGE ($1.60 PER YEAR) 40
SERVICE CHARGE BASED ON { METERED WATER / UNMETERED WATER
TOTAL

THIS BILL MUST BE PAID WITHIN 15 DAYS. BRING BILL WITH YOU.
(RATE INFORMATION ON BACK)

CITY OF OSHKOSH—SEWERAGE COMMISSION
SEPTEMBER 30, 1930

BALANCE
FIXED CHARGE 40
SERVICE CHARGE { METERED WATER / UNMETERED WATER
TOTAL

SEND THIS STUB WITH MAIL REMITTANCE

OFFICE COPY
SEPTEMBER 30, 1930

BALANCE
FIXED CHARGE 40
SERVICE CHARGE { METERED WATER / UNMETERED WATER
TOTAL
PAID
BAL.

CITY OF OSHKOSH — SEWERAGE COMMISSION
SEWER RENTAL RATES

Annual fixed or basic charge for each connection to sewer system—$1.60 per year (40c per quarter).

Service charges for users of city water are 50% of the consumption charge or minimum charge for water furnished the user. In determining this charge for residences, the average of the water bills rendered on the first days of April and July of each year is obtained and 50% of that average is the service charge for each of the four quarters of the year. This method is followed so as to eliminate sewer charges on water used during the summer months for sprinkling lawns and watering gardens, and applies to residences only. In cases where this average cannot be obtained because of change in occupancy or for other reasons, the actual water consumption is the basis for determining the sewer charge.

FOLIO..... ACCT. NO.....

NAME .....

STREET .....

TOTAL GAL. WATER CONSUMED - .....
DEDUCTIONS, IF ANY - - - - - .....
TOTAL GAL. TO BE CHARGED .....
MINIMUM CHARGE PER QUARTER
AMOUNT - - - - - - - - $
NO. OF DOWNSPOUTS AT 25C EACH PER MONTH
TOTAL - - - - - - - - $

FORM 27

TO CITY OF LEBANON DR., ACCT. NO. .....
CARD NO. .....

FOR WATER AND SEWAGE DISCHARGED INTO THE SANITARY SEWER

RECEIVED OF..... DATE..... TO..... 193...

STREET NO.....

OUT LOT	BLOCK	LOT NO.	ADDITION

TOTAL GAL. WATER CONSUMED.....
DEDUCTIONS, IF ANY - - - .....
TOTAL GAL. TO BE CHARGED - .....

..... GAL. AT 12C M $
..... GAL. AT 10C M
..... GAL. AT 9C M
..... GAL. AT 8C M
..... GAL. AT 7C M
..... GAL. AT 6C M
MINIMUM CHARGE PER QUARTER - - -
AMOUNT - - - - - - $
NO. OF DOWNSPOUTS AT 25C EA. PER MO.
TOTAL - - - - - - - - $

SEWER RENTAL EXPERIENCE

STATE & CITY	POPULATION	FINANCED WITH REVENUE BONDS	RATE BASIS: WATER CONSUMPTION	RATE BASIS: OTHER METHODS	BILLING METHODS: MONTHLY	BILLING METHODS: QUARTERLY	DELINQUENCIES	REMARKS ON COLLECTIONS
ARKANSAS								
Batesville	4,500	Yes		Flat rate	Yes			Citizens protest.
Brinkley	3,048	Yes		Flat rate	Yes			
Fordyce		Yes		Flat rate	Yes			Some difficulty due to protests.
Little Rock	80,000	Yes	Yes		Yes		6 to 8%	Some protest from tenants.
Stuttgart		Yes		No. of connections				
Waldron		Yes		Varies with service				Very little difficulty.
West Memphis	2,900	Yes		No. of fixtures	Yes		Negligible	Few protests.
FLORIDA								
Ft. Lauderdale	(Max.) 40,000	Yes	Yes		Large meters	Small meters	Less than 5%	
Tallahassee	15,000	No		No. of fixtures	Yes		0	A few protests on first bill.
GEORGIA								
Athens	22,000	No		No. of fixtures			5%	
ILLINOIS								
Anna	4,000	Yes		No. of connections		Yes	0	
Barrington	4,000	Yes	Yes			Yes	4½%	Few protests.
Belvidere	8,123	Yes	Yes			Yes	5%	
Edwardsville	6,500	Yes	Yes	Also flat rate	Yes		15%	Object to not having referendum
Effingham	5,301	Yes		No. of connections		Yes	10%	
Elmhurst	15,000	Yes	Com'l.	Flat rate residences	Yes		½%	
Kankakee	22,300	Yes		No. of fixtures	Yes (also bi-monthly)		6%	No unusual difficulties.
Kewanee	17,000	Yes	Yes				12%	No difficulties.
Libertyville	4,000	Yes	Yes			Yes	½%	
Monmouth	9,000	Yes	Yes		Yes		10%	
Rochelle	3,890	Yes	Yes			Yes		No difficulties.
Sullivan	3,300	Yes	Yes		Yes		¼%	No difficulties.
Waterloo	2,300	Yes		Flat rate	Yes		Very small	
West Chicago	3,900	Yes	Water & sewer combined			Yes	5%	
West Dundee	1,800	Yes		Flat rate		Yes	1%	Few mild protests.
INDIANA								
Bloomington	18,227	Yes	Yes (discharges into sewer)		Yes		1%	No difficulty.
Goshen	12,000	Yes	Yes (plus flat rate & connect. chg.)		Yes		10%	No difficulty.
Kokomo	32,843	Yes	Yes	Also flat rate	Yes		7%	Some objections at first—
La Porte	16,000	Yes	Yes	Flat rate	Large users	Small users	10%	none now.
Michigan City	30,000	Yes	Yes	Flat rate	Yes		10%	Very little difficulty.
Mitchell	3,226	Yes	Yes				0	
IOWA								
Cedar Rapids	60,000	Yes	Yes		Yes (also bi-monthly)		Very small	No difficulty.
Ft. Dodge	25,000	No	Yes			Yes		
Iowa City	15,340	Yes	Yes		Yes			Some protests.
Mt. Vernon	1,500	Yes	Yes			Yes		
KENTUCKY								
Beaver Dam	1,050	No		No. of fixtures	Yes		0	
Providence	5,000	Yes	Yes		Yes		8%	Slight difficulty with some.
Richmond	7,500	Partly	Yes	Also flat rate	Metered	Flat rate	0	Some objections to rate.
LOUISIANA				Flat rate on				
Jennings	6,500	No		water bill	Yes		2%	
MICHIGAN								
Ann Arbor	30,000	Yes	Yes		Partly	Yes	Less than 1%	No difficulty.
Battle Creek	45,000	Partly	Yes		Yes		4 to 6%	Some complaints.
Grand Haven	8,345	Yes	Yes		Yes		4%	
Jackson	55,000	Yes	Yes (based on winter months)		Yes			No difficulty.
Traverse City	13,000	No	Yes			Yes	5%	Difficulty at first only.
NEBRASKA								
Adams	535	No		Flat rate	Yes			
Blue Hill	889	No		Flat rate	Yes			
Columbus	8,000	Yes		Flat rate		Yes	Less than 1%	
Lawrence	528	No		Flat rate	Yes			
Peru	835	Yes		Flat rate	Yes			
Trenton	865	Yes		Flat rate	Yes			
NEW YORK				Balance charged				
Buffalo	563,000	Yes	Yes (55%)	against real property	Monthly, quarterly & semi-annually			
Plattsburgh	13,347	Yes		Flat rate and no. of connections				
OHIO								
Bedford	7,400	No	Yes			Yes		
Berea	5,697	No	Yes			Yes		
Bowling Green	6,688	No		Flat rate		Yes	Negligible	
Dayton	200,982	Partly	Yes (Modified)			Yes		
Findlay	19,363	Partly	Yes		Yes		6%	No serious difficulty.
Greenville	7,036	Partly	Yes			Yes	None	No difficulty.
Mansfield	33,525	No	Yes			Semi-annually	5%	A few protests at first.
Oxford	2,588	Yes	Yes			Yes		
Springfield	68,763	No	Yes			Semi-annually		
Toledo	290,718	No	Yes			Yes	20% but will be collected: loss not more than .03%	
PENNSYLVANIA								
Abington Township	18,500			No. of fixtures			None	
Cheltenham Township	18,200	No		No. of fixtures		Annually	Small	
Haverford Township	25,000	No		No. of fixtures		Annually	Few	
Jenkintown	5,000					Annually	Small	
Media	5,000	No	Yes	Also no. of connect'ns		Annually	5%	
Radnor Township	12,317			No. of fixtures		Annually	Small	
Springfield Township	5,000			No. of fixtures		Annually	Few	
U. Moreland Township	4,500	Partly				Annually	10%	
TENNESSEE								
Lawrenceburg	3,500	Yes		Flat rate	Yes		None	
Parsons	1,000	Yes		Flat rate	Yes		None	
TEXAS								
Alvin		No		Flat rate	Yes		5%	No difficulties.
Big Spring	15,500	No		Flat rate	Yes			
Brownsville	25,000	No		No. of connections	Yes		1%	Only few protests.
Corpus Christi	58,000	Yes	Yes (with		Yes		2%	Some difficulty because no
El Paso	102,000	Yes	min. charge)	Flat rate			None	deposit required.
Jasper	4,500	No		Flat rate	Yes		5%	
La Feria	1,600	No		No. of connections	Yes		10%	No protests.
Lufkin	10,000	No		No. of fixtures		Yes	None	
Mineral Wells	7,000	No		No. of fixtures	Yes		10%	
Raymondville	3,800	No		Flat rate & fixtures	Yes		30%	Owners and renters disagree on
Snyder	4,000	No		Connections & fixt.	Yes		None	who should pay.
Sweetwater	15,000			Fixtures	Yes		None	
Wharton	3,600		Yes	Minimum & fixtures	Yes		None	
VIRGINIA								
Berryville	1,200	Yes		Flat rate		Semi-annually	10%	
Christiansburg	2,000	No		Flat rate	Yes		4%	
Herndon	1,000	Partly		Flat rate		Yes		
Roanoke San. Dist.	6,000	Yes		Flat rate		Yes	None	
Williamsburg	2,778	No		Flat rate		Yes	4%	
Winchester	12,500	No		Flat rate		Annually	1%	
WISCONSIN								
Oshkosh	40,108	Mostly	Yes	Flat rate		Yes		

(We recommend to the reader the 120-page brochure "Sewer Rentals," published by the American Public Works Association, 1113 East 60th St., Chicago.—Cost to non-members, $1.50.—Ed.)

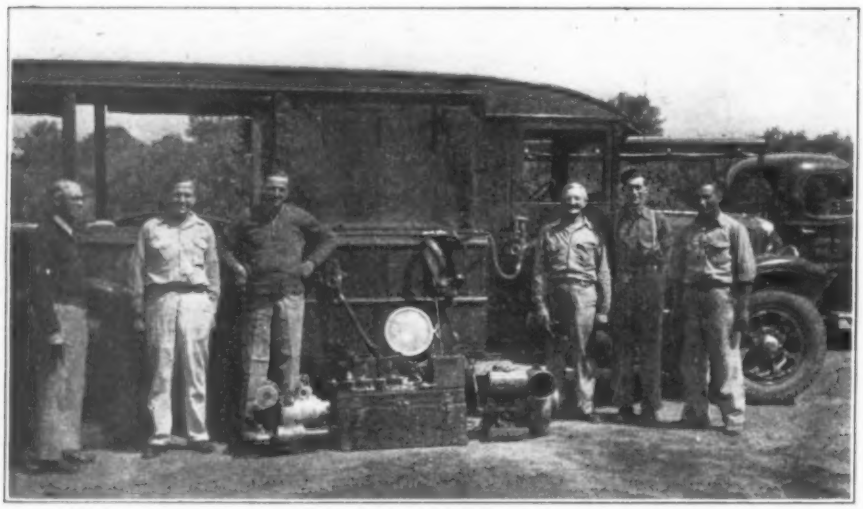
SEWER SERVICE AND MAINTENANCE

Radio Equipped Service and Maintenance Truck Proves Its Value

By EDWARD P. DECHER

Ass't. Secretary and Purchasing Agent
The Joint Meeting, Newark, N. J.

First, it should be explained that the Joint Meeting is a Sewer Commission and is comprised of the following eleven municipalities: City of East Orange, Town of Irvington, Township of Maplewood, Township of Milburn, City of Newark, Village of South Orange, and the Town of West Orange, all being in the County of Essex. In the County of Union are the Township of Union, Township of Hillside, Boro of Roselle Park, City of Summit.



No. 1.—Radio Equipped Maintenance and Service Truck and Equipment (Henry Decher, Ass't Foreman (left) and Crew)

The Joint Trunk Sewer

The Joint Trunk Sewer is constructed within the boundaries of the aforementioned municipalities. The original sewer was built in the year 1900 and is approximately 23 miles in length. A Supplementary Joint Trunk Sewer was completed in the year 1930 to give a total of 54 miles of main trunk sewer in all.

The Joint Trunk Sewer at the present time is serving an estimated population of about 305,000. The Sewage Treatment Plant is located in the City of Elizabeth, the final effluent discharging into Arthur Kill. One can readily see that should our men and equipment be working in the Town of West Orange and an emergency should arise in the Boro of Roselle Park or at our Treatment Plant (the plant being about 12 miles from the Town of West Orange) a difficult task would be encountered in contacting the men or securing needed equipment.

Our Truck Now Radio Equipped

Because of the distances involved it was deemed advisable by the Hon. Peter A. Smith Chairman of the Joint Meeting, to equip one truck, at least, with a short-wave receiving set for the purpose of reaching our maintenance and service crew in the shortest possible time in case of an emergency or a complaint received which justified attention with least delay.

The radio set was purchased at a cost of $170.00 and installed on our three ton International truck.

The following is a list of the equipment carried on our two motor trucks:

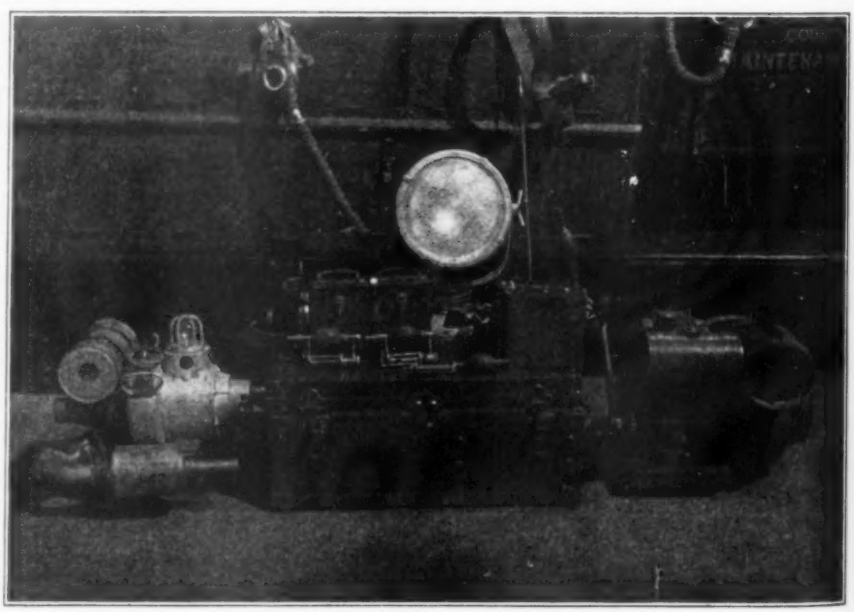
1 Hydrogen Sulfide Detector.
1 Wolf Safety Lamp.
1 Combination Velocity Blower Hose Mask with Safety Harnesses.
1 Carbon Monoxide Detector.
2 Canister Type Gas Masks.
Carbon Monoxide Detector Ampoules.
2 Pairs Chippers Goggles.
1 2½" Portable Air Blower.
1 Combustible Gas Indicator.
1 Industrial First Air Kit.
4 Extra Safety Belts with ropes attached.
Salt tablets for use in the prevention of heat sickness.
1 1500 Watt Portable Electric Generator and Floodlights.

The Joint Meeting has six employees on General Sewer Maintenance (see photo No. 1) and all of these men have taken a course in First Aid which course was given by the Newark Safety Council. Besides being capable of administering first aid, all of the men are trained in the proper use and operation of the many safety devices carried on our equipment at all times.

Our ment are especially instructed in the use of the hose and canister type masks. The Joint Meeting will not permit any of its men to enter a sewer or any sub-surface structure with a *canister* type mask which is of no value in oxygen deficient atmospheres.

We have heard of water service trucks that have been radio equipped. However, at the present time, I know of no other sewer truck equipped the same as the one owned and operated by the Joint Meeting, and I believe that it is the first sewer truck in the United States equipped with radio.

In photograph No. 1 is seen the two maintenance trucks (the larger being the radio equipped unit), some of the equipment



No. 2.—Some of the Equipment (See text for description and uses)

listed above (see Photo No. 2), and the General Maintenance Crew.

Equipment

Portable Generator

On the left is our indispensable Homelite Portable Generator good for 110 volts D.C. and 1250 Watts. In center, the floodlight. Both are products of the Homelite Corporation of Port Chester, N. Y.

With this generator we have several electrical tools and flood lights. These electrical tools have been found to be very satisfactory. We have never at any time found ourselves without proper lighting when emergency work is performed at night. We have approximately 200 feet of special extension cord, should the necessity ever require special lighting in our large sewers when repairs are made. A good portion of our sewers are in outlying territory where electric current to be supplied from a nearby house is impossible.

It may be interesting to note that the Joint Meeting has two cast iron pipe sewers, one being 36 inches in diameter and the other 54 inches, which run parallel and lie on the top of the ground in the Townshiip of Union and each being approximately 1500 feet in length without any manholes. It has been recommended by the Chief Engineer—Leslie E. West—that at least four manholes be built on each line and the type recommended are Hat-Flanges, with bolted covers. To install these Hat-Flanges our portable generator will play a very important part, that is for furnishing the current to drill the necessary holes in the present pipe in order to fasten on the Hat Flanges. If it were not for this machine it would require drilling these holes by hand or renting the equipment.

On two occasions power failures were encountered at the Treatment Plant. We were able to supply the necessary light until the current was restored. Our generator has proven a very sound investment, if not an indispensable one.

Blower, Hose Masks and Gas Detectors

The next item in this photograph is the trunk-like case which contains the blower and the hose type gas masks. This piece of equipment is manufactured by the Davis Emergency Equipment Company, Inc. of New York City. On the top of this case are two carbon monoxide detectors, two hydogent sulfide detectors, and one combustible gas indicator. The last two items of equipment are products of the Mine Safety Appliance Co. of Pittsburgh, Pa.

Portable Air Blower

The last item in this photograph is the portable air blower (on the right) manufactured by the B. F. Sturtevant Company of Boston.

This piece of equipment has proven very satisfactory and is used in ventilating sewers before men are allowed to enter. It has also been used at our Treatment Blant in drying out the tunnels. There also appears on this photograph, hanging from the side of the truck, the headpiece and safety belt of the gas mask. This equipment as shown is carried at all times with the necessary First Aid equipment on this truck. A combustible gas indicator manufactured by the Davis Emergency Equipment Co., together with the duplication of the carbon monoxide and hydrogen sulfide detectors are carried on our other truck, and another set is stationed at our Treatment Plant.

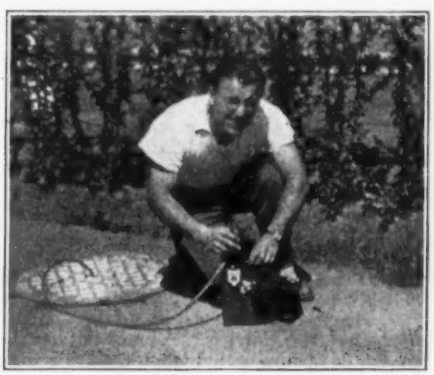
The writer believes that no municipality can afford to be without the necessary safety equipment for the protection of their employees. While the cost of the aforementioned equipment is most reasonable, it is priceless in the event of an emergency.

No. 3.—We find the Flexible Rod to Have Many Advantages Looking into the manhole are Henry Decher, Foreman, and (right) Corey W. Sanford, Superintendent of Sewers.

No. 4.—Pollard's Portable Platform Derrick (On the platform, a turbine wench; Superintendent Sanford, Portable Homelite Generator and Flood Light)

Flexible Sewer Rods

The Flexible Sewer Rod shown in Photograph No. 3 has proven to be a very satisfactory piece of equipment. This piece of equipment, manufactured by the Flexible Sewer Rod Co. of Los Angeles has many advantages, such as can be seen. One can readily understand that the old method used in removing an obstruction in a sewer that only one man could be placed in a manhole, in a cramped position, at a time, thereby reducing his strength to a minimum when working. With a flexible sewer rod you can notice in the photograph that more than one man can be used and greater



No. 5.—Our Chief Engineer, Leslie E. West, Demonstrates the Test for Poisonous and Combustible Gases

pressure exerted, and the safety feature is that the men are on top of the ground at all times during this particular operation. We have found that an obstruction can be moved much faster with this piece of equipment than the methods used heretofore, and that more territory can be covered in a shorter time. There are also many other advantages.

Portable Derrick

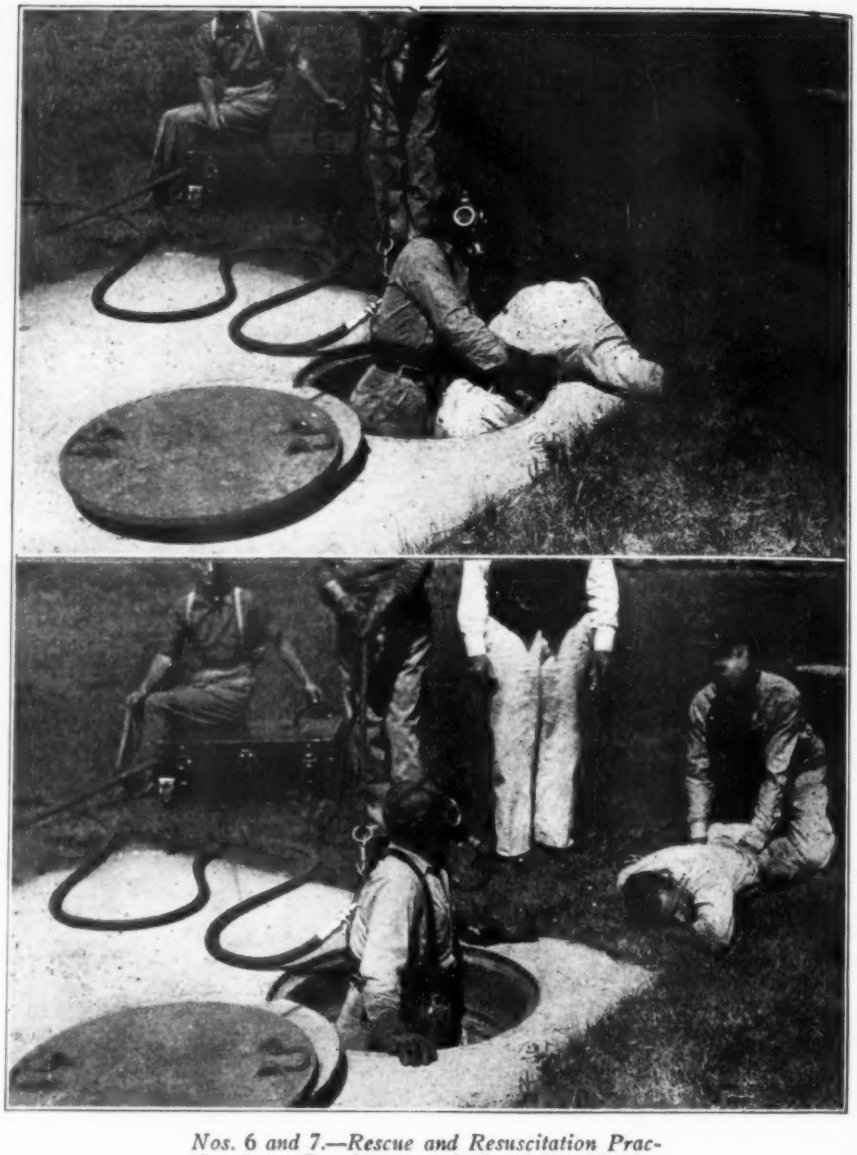
The portable derrick shown in Photograph No. 4, manufactured by The G. J. Pollard Company of Brooklyn, N. Y., is known as the Pollard Portable Derrick. The platform on this derrick is large enough to transport our two Turbine Sewer Cleaning Wenches (Turbine Sewer Machine Co. of Milwaukee) with the drum and cables intact.

These wenches, with the drums and cables, are rather heavy but can be easily placed on the derrick platform without much effort, due to the fact that the platform is only 12 inches above the ground. This platform derrick is equipped with a set of small rubber wheels in the center, and is towed on the rear of our truck from one job to the other.

The derrick has a lifting capacity of 1000 lbs. and can be swung in any position desired. It has been used to lower pipe on some of our repair jobs, and used in raising tilting buckets out of manholes during sewer cleaning operations. It has also been used very successfully in loading heavy manhole heads and pipe on our truck, therefore making loading much safer. This piece of equipment has proved highly useful.

Rescue and First Aid Practice

Photographs No. 6 and No. 7 show our employees giving a demonstration of the proper method of rescuing a man, should he be overcome while working. There may be a possibility that the reader seeing the photograph may criticize the fact that we permitted a man to enter a sewer or chamber without the proper equipment. however, this is not the case with the Joint Meeting. I believe, though, that the fact can be appreciated that it is a hard task to have a man working in a sewer wearing a gas mask continuously, if the conditions under which he is working are absolutely safe. Extensive tests are made before any man is permitted to enter any of our sewers. We have quite a number of meter chambers which are far above the sewer line itself. These must be entered by our employees each week to change the meter charts, and in performing this duty it is not always necessary for a man to be equipped with a mask if conditions are safe, however, one can never tell when an employee may be suddenly attacked by some gas. For this reason our employees must go through a rehearsal such as pictured, so that they do not lose their technique and ability in case of an emergency.



Nos. 6 and 7.—Rescue and Resuscitation Practice Is a Requirement of the Joint Meeting

Compensation Insurance

The Joint Meeting carries compensation insurance, which we believe is very necessary. Regardless of how minor an injury may be, even to a small scratch on the finger, the employee must go to a doctor for the necessary treatment. This is to insure their safety and to minimize claims against the Joint Meeting.

Last year all of the employees of the Joint Meeting were inoculated against typhoid fever. This was paid for by the Joint Meeting as a safeguard to its employees. The Joint Meeting makes every effort to see that its employees are protected from any hazards and makes it a practice to have a safety engineer from the insurance company make regular inspections of the equipment and Treatment Plant every month. And, at the same time the inspection is made a safety meeting is held by our employees, they having an opportunity to discuss problems pertaining to the plant with the safety engineer.

Safety Equipment Demonstrations

In June, 1938 the Commissioners of the Joint Meeting held a special meeting at the Treatment Plant for the purpose of gaining as much knowledge as possible for themselves and the employees on safety measures. The principle speakers at the meeting were Mr. E. M. McCool of the Mine Safety Appliance Co., and Mr. L. W. Brendlen of the Davis Emergency Equipment Co. They gave a very splendid lecture and demonstration on the proper uses of the various safety devices used in connection with sewer work. This meeting was attended by approximately 100 officials connected with the municipal sewer departments in Essex and Union Counties, New Jersey.

Employee Suggestion-Box and Prize Contest

There is installed on the wall in the Treatment Plant a box known as the Suggestion-Box in which suggestions are deposited by our employees. Employees have continuously placed suggestions in this box and, after being given careful consideration, the most practical are tried. A number of the suggestions submitted have been found to be decidedly beneficial. It is a commonly known fact that men in constant contact with equipment are those most able to express its advantages and observe wherein improvements would bring about better results. The Commissioners of the Joint Meeting have discovered that many of these suggestions have resulted in a considerable saving in dollars. For this reason the Commissioners of the Joint Meeting have set up two prizes for a contest which is now in progress, giving each employee an opportunity to express his views as to what in his opinion would better serve the Joint Meeting as operation of the Treatment Plant, maintenance of the sewers, safety of the employees, or any other item pertaining to the works in general.

USEFUL TECHNIC IN GROUND WATER INFILTRATION STUDIES*

By CHARLES A. McLOUGHLIN, C.E.
Past Asst. Engineer (R), U. S. Public Health Service

A SYSTEM of approximately 3.5 miles of 8- and 10-in. vitrified tile gravity sanitary sewers has been constructed to serve two war housing projects in a southern Connecticut town. These sewers discharge to a common 10-in. vitrified tile line to a pumping station (Fig. 1), from which the sewage is raised to the town sewage treatment plant. Upon completion of the system and before occupancy of the projects, the town objected to placing the pumping station in operation. It was contended that ground water infiltration was excessive and would aggravate conditions at the already overloaded treatment plant.

A study of the contract specifications revealed that no infiltration limit had been set. The standard specifications established a maximum infiltration rate of 10,000 gal. per day per mile of sewer regardless of diameter. It appears that some consideration should be given to the size of pipe used. A more commonly used criterion which takes this factor into consideration is usually stated as follows: "Ground water infiltration shall not exceed one gallon per hour per inch diameter per 100 ft. of sewer." The latter criterion establishes an infiltration limit of 10,140 gal. for 8-in. and 12,670 gal. for 10-in. sewers per mile per day. The town officials alleged that this limit was considerably exceeded and, if secured, would be acceptable.

The sewers were constructed of vitrified clay bell and spigot pipe with poured bitumastic joints. A considerable amount of ground water was encountered during construction, particularly in the off-site or out-fall sewer between manhole No. 5 and manhole No. 0. There is a constant head of ground water of from 4 to 6 ft. over the 480-ft. length of pipe between manhole No. 2 and manhole No. 0. The material encountered in excavation closely resembled quicksand. In spite of these conditions no special precautions were prescribed in the specifications for laying the sewer in this section, and no extraordinary care was taken by the contractor other than pumping the excavation nearly dry during the pipe-laying operation.

In making the investigation reported here, it was first determined that none of the dwelling units in these projects was occupied; the water supply to the units was shut off at the meter pits. Tests were made at various points in the water distribution systems to be certain that none of the supply would reach the sewers and that the only flow in the sewers would, therefore, be due to ground water infiltration.

In order to determine the flow, tests were made at manhole No. 0 over the wet well of the pumping station. A portable, gasoline motor-driven diaphragm pump was set up with the suction intake in the well. The speed of the pump was regulated so that the water level in the well remained constant, and pumpage was equivalent to the flow into the well. A 55-gal. steel drum was set up and filled by the pump discharge and the time required to fill it was carefully noted. This operation was repeated three times, and the average time required to fill the drum was 51 seconds. This is equivalent to a flow of 93.312 gal. per day, which amounts to an infiltration rate of 26,600 gal. per day per mile of sewer. On the basis of the criteria hereinbefore discussed, this rate of infiltration is more than twice that usually permitted.

Use Stopper to Plug Off One Sewer

An efficient stopper was made (Fig. 2) and used to plug the up-stream 10-in. pipe in manhole No. 5. The flow then entering the wet well was solely infiltration into the off-site sewer from manhole No. 5 to manhole No. 0, a distance of approximately 1,500 ft. Using the procedure outlined in the foregoing paragraph, the 55-gal. drum was filled and emptied four times and the average time of filling determined at 81 seconds. This is equivalent to a rate of 0.68 gal. per second, or 58,752 gpd., or 207,000 gpd. per mile of sewer.

By deducting the flow determined for the off-site sewer (58,752 gpd.) from that in the entire system (93,312 gpd.), infiltration into the on-site sewers was established at 34,560 gpd., or at a rate of approximately 10,740 gpd. per mile of pipe. This rate of infiltration is within the usual requirements for a system composed of 10-in. and 8-in. sewers.

It was evident from these tests that most of the infiltration to the system was occurring in the off-site sewers from manhole No. 5 to the pumping station, a distance of approximately 1,500 ft. Tests were undertaken to localize this condition more definitely. A stopper was inserted in the influent sewer at manhole No. 2 and further flow tests at the wet well revealed a flow for the 480 ft. of pipe from manhole No. 2 to manhole No. 0 of 50,112 gpd., or an infiltration rate of some 506,800 gpd. per mile of sewer. Deducting the flow of 50,112 gpd. from the flow previously determined for the sewer between manhole

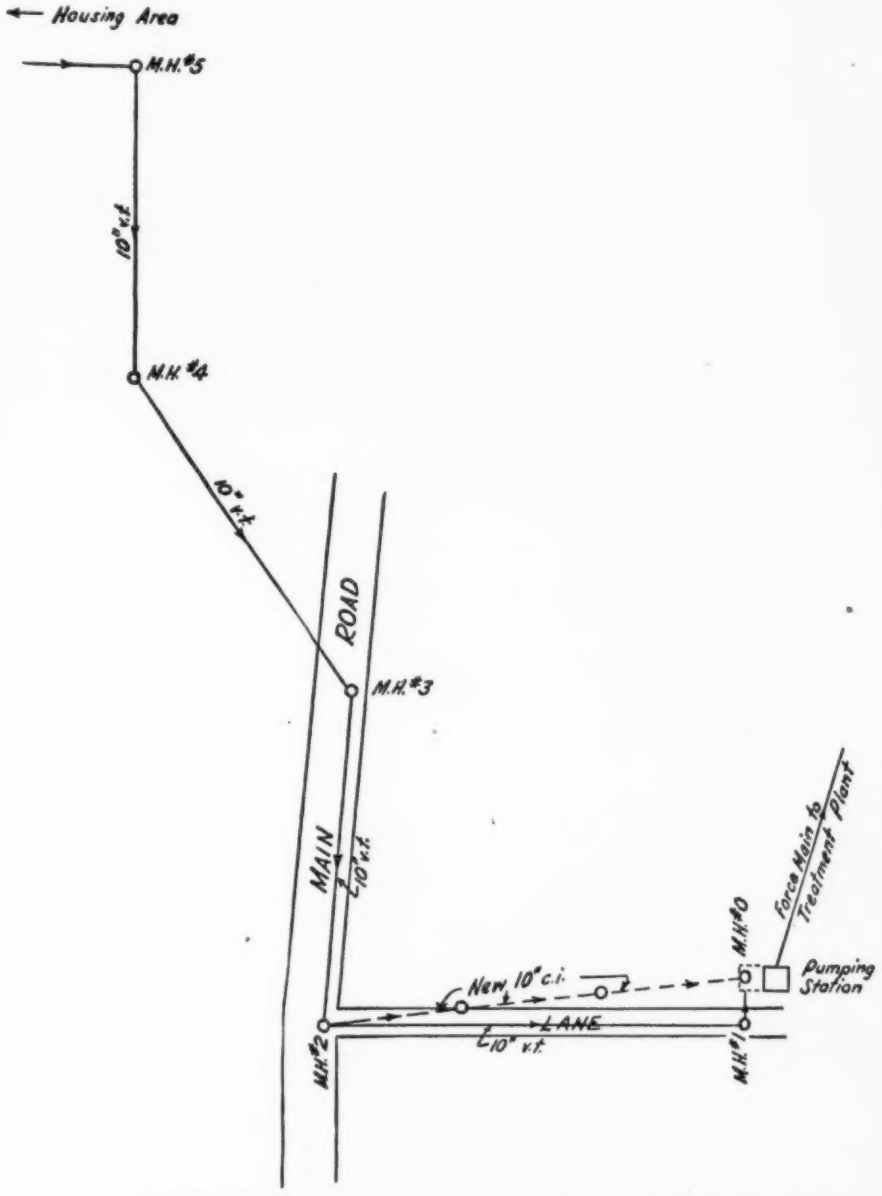


Fig. 1.—Off-Site Sanitary Sewer from Housing Area to Pumping Station.

*From *Sew. Wks. Jour.*, Sept., 1945. Reprinted by permission of the Fed. Sew. Wks. Assns.

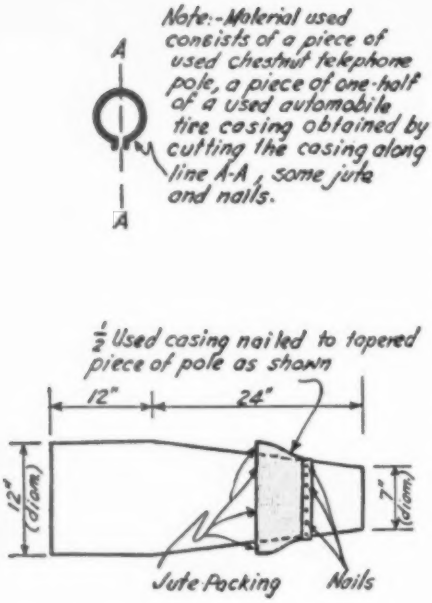

Note:-Material used consists of a piece of used chestnut telephone pole, a piece of one-half of a used automobile tire casing obtained by cutting the casing along line A-A, some jute and nails.
A
A
½ Used casing nailed to tapered piece of pole as shown
12"
24"
12" (diam)
2" (diam)
Jute Packing
Nails

Fig. 2.—Detail of Sewer Plug Used in Making Infiltration Studies.

No. 5 to manhole No. 0 of 58,752 gpd., a flow of 8,640 gpd. is obtained for that stretch of sewer between manhole No. 5 and manhole No. 2. This is equivalent to an infiltration rate of 44,700 gpd. per mile of sewer, or 3 to 4 times that which would be permitted by the town.

From a study of the quantities of flow obtained for the entire system and its component parts it was evident that, to obtain an infiltration rate for the entire system that would be acceptable to the town, it would be necessary to overcome nearly all of the infiltration to the 10-in. sewer between manhole No. 2 and manhole No. 0. If infiltration could be entirely eliminated in this sewer, the resultant infiltration rate for the entire system of sewers would be reduced to 12,300 gpd. per mile of sewer.

The influent 10-in. sewer to manhole No. 1 was plugged and the flow into the wet well was negligible, indicating that infiltration in this short line could be disregarded.

It was necessary to devise some means of determining the cause of the excessive infiltration of ground water to the sewer between manhole No. 2 and manhole No. 1, so that the most effective corrective measures could be prescribed. Leakage could possibly be due to one or several breaks in the line, or to uniform leakage through the pipe joints. It was decided that if a watertight plug could be installed in the 10-in. sewer, starting at manhole No. 2, and moved in successive stages toward manhole No. 1, with flow measurements being taken at each stage, the existence of ary major breaks would be detected and located.

Punching Bag Stopper

A standard pear-shaped punching bag was purchased at a local sporting goods store; the maximum diameter of the bag was 10 in. By opening some of the stitched seams in the cover and overinflating the bag slightly, a tight fit in a 10-in. pipe was obtained. Three hundred feet of strong sash cord was supplied by the contractor. The end of a ball of mason's line was tied to a small block of wood and the block floated through the sewer from manhole No. 2 to manhole No. 1, as the line was paid out. Then the sash cord was tied to the line and drawn through the sewer to manhole No. 1. The end of sash cord at manhole No. 2 was tied to the punching bag by means of the loop in the cover at the top of the bag. The bag was thoroughly greased before being inserted in the 10-in. line at manhole No. 2.

The punching bag was drawn in successive 20-ft. increments to manhole No. 1 and the depth of flow in the pipe at manhole No. 1 was measured at each stage. The decrease in flow was uniform as the plug was drawn through the pipe. There was no abrupt change in the rate of decrease in flow until the plug was drawn to within 150 ft. of manhole No. 1. Over the distance from this point to manhole No. 1 there was enough decrease in flow to indicate that this portion of the 10-in. sewer had been properly laid and did not allow excessive leakage.

It was concluded from these studies that the ground water infiltration rate for the entire system of sewers in the amount of 26,600 gpd. per mile of pipe was excessive; that the infiltration rate to the on-site sewers of 10,740 gpd. per mile of pipe was within allowable limits; that most of the excessive infiltration of ground water took place over a distance of approximately 330 ft. measured in the direction of flow from manhole No. 2; that the sewer from manhole No. 2 to manhole No. 1 was reasonably straight and clean and free from bad breaks; and that the excessive infiltration in this sewer was attributable to fairly uniform leakage at the joints.

In view of existing soil conditions, involving the laying of vitrified clay pipe in fine sand under an abnormally high head of water, it was felt that additional precautions should have been taken in specifying the method of pipe-laying.

A new sewer line was recommended for construction between manhole No. 2 and manhole No. 0, by-passing manhole No. 1, a new manhole to be provided midway in this new line. It was further recommended that cast-iron pipe be used and that additional construction precautions be taken, including provision for broken stone ballast under and around the pipe, leaving sheeting in place, and provision for removal of all ground water from the trench while pipe was being laid.

The new sewer line has been constructed essentially as recommended, abandoning the original lines between manholes Nos. 2, 1 and 0. The town officials, after inspecting and testing the new line, approved the system.

SAFE COLUMNS FROM STANDARD PIPES

By W. F. SCHAPHORST, M.E.
Newark, N. J.

Ordinary pipes often come in handy for use as columns or struts or for use as "push members" in transmitting forces. Due to its circular form, pipe is ideal.

However, when it comes to "figuring columns," it usually takes considerable time digging around in handbooks, etc., and as a result the use of a pipe is avoided. Or, a pipe much too large or too small is used, chosen entirely by "guess." The pipe that is too small may fail and be the cause of disaster.

Those who may have occasion to use standard pipes in this way will find the following simple table and rules of value:

1. Knowing the load that is to be carried and the length of pipe needed, make a "guess" as to the size of pipe. Column A in the tables will help in making the guess as it gives the maximum length of pipe that may be used. Thus, never use a ⅛-in. pipe, as an important column, longer than 14.5 in. Never use a 3-in. pipe, as an important column, longer than 139 in., etc.

2. Multiply the length of the pipe in inches by the corresponding figure in column B of the table. This product should never be greater than 12,000. If it is greater than 12,000 it means that you have guessed a pipe that is too small. After getting the right size, proceed as follows:

3. Subtract the product from 19,000. If the difference is equal to or less than 13,000 use it, in (4). If the difference is more than 13,000 use 13,000 in (4).

4. Multiply by the figure in column C, corresponding with the pipe size.

The result is the number of pounds that the pipe will carry as a column, strut, or "push member." If the result is less than the load to be carried, try again, using the next larger pipe size, and so on until the proper and most economical size is selected.

Size of Pipes, Inches	Column A Maximum Length, Inches	Column B	Column C
⅛	14.5	826.4	0.07
¼	19.4	617.3	0.12
⅜	25	480.8	0.17
½	31.3	383.1	0.25
¾	40	300.3	0.33
1	50.6	237.5	0.50
1¼	64.7	185.5	0.67
1½	75	160.5	0.80
2	94.7	126.9	1.07
2½	114	105.3	1.71
3	139	86.21	2.24
3½	161	74.63	2.68
4	181	66.23	3.18
4½	202	59.52	3.68
5	226	53.19	4.32

Example: It is desired to support a load of 10,000 lb. at a height of 84 ins. What size of pipe should be used? Following the rules, we do this:

1. "Guessings" the size of pipe, column A shows that 84 ins. falls between 1½ and 2-in. pipe. We will therefore try a 2-in. pipe.

2. 84 × 126.9 = 10,650. This is less than 13,000 and we may therefore use it in (4). If the difference were 18,350, we would have to use 13,000 in (4).

3. 19,000 — 10,650 = 8,350. This is less than 13,000 and we may therefore use it in (4). If the difference were 18,350, we would have to use 13,000 in (4).

4. 8,350 × 1.07 = 8,950 lb.

Since 8,950 lb. is less than 10,000 lb. a 2-in. pipe is too small. We will therefore recalculate, this time trying a 2½-in. pipe.

2. 84 × 105.3 = 8,850.

3. 19,000 — 8,850 = 10,150.

4. 10,150 × 1.71 = 17,370 lb.

This shows that a 2½-in. pipe would be amply safe to hold up 10,000 lb. It shows that a 2½-in. pipe is capable of holding the load safely.

PROPER SEWER JOINTING

And Other Effective Construction Procedures to Preclude Infiltration

By WILLIAM A. GOFF
Consulting Engineer, Philadelphia, Pa.

The method of constructing joints in sewer pipes is directly related to the success or failure of the construction of a sewer system.

Those who are conversant with the many factors in the design of a sewer system, sewage treatment works, and allied units of construction, know the importance of restricting infiltration of the pipe lines to a minimum.

The extent of infiltration is not only indicative of the general character of construction of the work performed. Low infiltration leads to economy in the operation of the system and works and reserves for future use the capacity of the pipe lines and works that otherwise would have been utilized through the conveyance of needless volumes of ground water.

The effort put forth today in the treatment of sewage, which in a majority of cases requires initial pumping and in many instances secondary pumping, emphasizes the need of tighter sewers. It is readily discernible that every drop of water that enters the lines and is pumped and treated, invoives costs.

There are unquestionably numerous factors directly related to the infiltration of pipe lines, but there can be no question that the most important factor entering into this particular phase of construction is the method of constructing the joints.

In the established practice of awarding contracts to the lowest bidder, there is little or no definite assurance of the qualifications of the men who will do the work. Under prevailing conditions in public contracts a contractor is not selected on his record of satisfactory construction performance, but rather upon the price bid. While a contractor himself may be most willing to perform his contract satisfactorily, it is actually the men who work in the trench who are the keystone of performance.

The Importance of Exacting Specifications.

To afford these men the opportunity of producing satisfactory results, the engineer must of necessity know the conditions under which these men are to work, and provide in his specifications such methods of construction as will enable these men to perform their work in a satisfactory manner. In addition, the contractor must cooperate with all of his facilities in an endeavor to produce the results desired. It is this thought that I have uppermost in my mind when planning and designing a system of sewers, for I fully realize that unless the men who actually do the work are provided with a suitable method of construction, the finished product will not be satisfactory regardless of their efforts.

I have found that where a large portion of the sewer joints are to be under three or four feet head of water, that the dewatering of the trenches by the method of well points, has been the most successful means of providing favorable working conditions for the men making the joints in the trench.

Value of Trench Dewatering by Well Points.

This pre-draining of the construction area prior to the commencement of excavation does three things:

First—It provides the contractor a dry ditch in which to work and also gives the inspector a better chance to inspect the joints.

Second—It reduces by a considerable amount the need for sheeting and shoring. In the majority of cases of pre-draining the sides of the bank will remain standing, even in sand, with only skeleton bracing.

Third—It eliminates all needs for special construction, such as concrete encasement or cast iron sewer.

All of these things affect the cost and incidentally help to create tight joints, all of which is very important.

After affording favorable working conditions for the men in the trench, the next step is to provide a suitable joining material and the method of its construction to obtain the desired objective.

The Most Effective Joint.

Outstanding are the bituminous joints, both hot and cold. Basically they are composed of coal tar or asphalt, mixed with powdered inert materials and either poured into the joint while hot and allowed to cool, or preformed joints inserted in the joint space and pushed in place when the pipes are assembled.

Jointing with hot poured compounds has the advantage of completely filling the annular joint space, more permanent adhesion to the pipe sides, and a degree of resiliency which will permit slight movements of the pipe line.

Preformed joints have made their appearance on the market and have been used with various degrees of success. One preformed joint, consisting of collars of felt impregnated with these asphalt compounds, made in sizes to fit the commercial pipe sizes, is slipped over the spigot end of the pipe and forced along with the pipe by means of a mechanical jack, into the bell of the receiving pipe; the natural resiliency of the preformed joint distorting to fit the shape of the bell and spigot. Another preformed joint which has been used with good results is made by the use of metal dies clamped in the bell and around the spigot of pipes and poured with hot compound prior to lowering the pipe into the trench. At the time of assembly the two preformed collars are painted with a solvent and pushed together the solvent causing the collars to fuse and thus form the joint.

Jointing Experience

The type of joint which I have been using for the past seven years is the result of numerous experiments and actual field tests, and consists of the following:

Oakum packing of approximately 1-inch in depth.
A hot bituminous joint of approximately 1½ inch in depth, and an outside cement mortar fillet wrapped in a muslin cloth tied tightly in place.

Such a joint sounds complicated, but my experience shows that after the ditch-men become experienced, the joint can be made rapidly and consistently perfect. Perhaps this joint does add a few cents to the per foot cost of the sewer, but what of that. The owner is buying a sewerage system and he wants a good one. It is distinctly worth while to avoid infiltration and all will agree that there is only one time to get tight construction and that is when the sewer is built. Any small initial increased cost of construction is soon compensated by the economies possible where the infiltration is negligible.

Laying Specifications.

In the construction of the joint I specify, the pipe be laid by two men, one holding the spigot end of the pipe in a "U" shaped sling consisting of perhaps two strands of jute at the end of the pipe while the other man pushes the pipe home from the bell end. After the pipe is home the front man wraps the oakum over the pipe and pushes it in place with a caulking iron, so as to provide proper space for the bitumen, while the back man tests the pipe for elevation with a grade rod from the line above and checks for line by a plumb bob from the same line, and makes such adjustments as necessary. He then moves forward, checks the subgrade for elevation and excavates bell and a length four inches longer than the circumference of the last pipe laid and determines if it is free of water. The next pipe is then handed down into the ditch and laid as before. The top man, before handing the pipe down, ties on the bell end of each pipe a piece of muslin with a width of six inches greater than that of the bell and a length four inches longer than the circumference of the bell. This cloth has been torn to provide tie strings at each of the four corners. Another man follows behind and places around each bell a runner fastened

From Proceedings of the Twelfth Annual Conference of the Maryland-Delaware Water and Sewerage Ass'n.

with a clamp at the top. Into this runner mouth he pours the hot joint compound, being careful to keep runner filled at the top and see that there is no leak at bottom or sides.

When cold, the runner is removed and the muslin band pulled out under the joint and completely filled with a cement-sand mortar (1:2) to form a 45° fillet around the outside of the bituminous joint. The mortar is pushed under the pipe to fill the band and the cloth band is then pulled tightly up and tied with the two remaining strings across the top of the pipe. The joint man then encircles the pipe with his hands and makes sure that the muslin band is completely packed with mortar, *especially at the bottom*, and that the band is tight. He then draws his hands upward, pressing the joint and dresses the top. Of course the mortar must be fairly stiff. It is not as complicated as it sounds, and contractors who have worked under me are generally enthusiastic after their men get the swing. It makes a *good* joint. The men know it. The inspector can check it. The contractor can see it and knows that future infiltration trouble is ended.

Features of This Joint.

The joint itself is correct. The oakum prevents the bitumen from getting into the pipe. The runner forms a tight channel for the bitumen which fills the annular space, adheres to the pipe surface and forms a tight joint. The bitumen can be readily inspected when the runner is removed. The cement collar reinforces the bitumen and provides maximum reinforcement where there is the greatest chance of a slip in the bitumen joint. That is as always, at the bottom. If by accident there should be a poorly poured bitumen joint the tightly packed cement mortar fillet will be forced into the hole and the rag will hold it there while the mortar hardens. The mortar fillets tends to give rigidity to the joint. The rag prevents backfill on a freshly made joint from disturbing the joint.

Results.

Results in the use of this joint have proven remarkably successful. Nowhere have contractors failed to meet the severe infiltration limitations I have set up in my specifications where I have used this joint.

In Harrington, Delaware, for instance, we constructed 8.08 miles of sewers, of which about fifty per cent was wet trench with an infiltration only 6.6% of the allowable.

In Berlin, Maryland, we constructed 7.97 miles of sewer of which 30% was wet trench with an infiltration only 7% of the allowable.

Other Records	Miles	Percent of allowable
Spring City, Pa.	9.59	27
Florence, N. J.	12.14	20
Conshohocken, Pa.	25.08	3
Georgetown, Del.	8.36	21
Clarks Summit, Pa.	18.99	68

Think of it, even in the last case we have a 19 mile system with a total infiltration of only 3,790 gallons a day, or less than three gallons per minute. Then consider that a ¼-inch hole under a two foot head of water will give a flow over one-half gallon per minute.

The infiltration limits I specify are as follows:

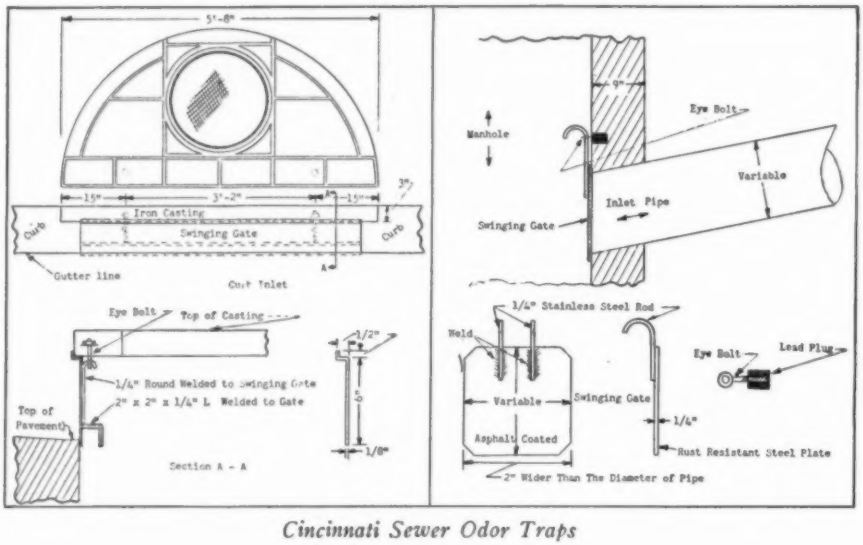
Size of T. C. Pipe-inches	Gallons-per mile in 24 Hours
5— 6	4,000
8	5,000
10	6,300
12	7,500
15	9,500
18—36	15,000

In the above mentioned list of recent jobs well points were used on Harrington, Delaware; Berlin, Maryland; Florence, New Jersey, and Georgetown, Delaware. In all of these instances quicksand was met and in no case did we use any special construction method.

Backfilling.

In backfilling the trench care must be taken to use only fine soft earth around the pipe in order to minimize the possibility of cracking the pipe. This initial backfill should be placed equally on both sides of the sewer to prevent dislodging and be carried at least one foot above the top of the pipe and carefully tamped to insure equal solid side foundation around the sewer pipe.

SEWER ODOR TRAPS FOR MANHOLES AND INLETS



Cincinnati Sewer Odor Traps

To hold in sewer gases and prevent the emanation of objectionable sewer odors from storm inlets to combined sewers and sewer manholes the here sketched swinging flap-gate arrangement has been designed and installed in Cincinnati by the Department of Public Works.

The trap for inlets (left) consists of a swing gate of ⅛ in. metal, fabricated and installed as sketched. The gate flap, reinforced and weighted with an angle iron welded across the bottom, opens inward under force of storm water and returns to closed position thereafter.

The trap for manholes consists of swing gates on all inlet sewers entering the manhole (right) and are apparently intended to preclude odors and gas from working back up-sewer rather than to prevent odors emanating at the top of the manholes so equipped. Naturally, the latter source of sewer odors can be corrected by plugging what appear to be of more hazard and detriment than of help—the vent holes in manhole lids—and employing rattle preventing "Tapax," or its equivalent, for sealing the space between the lid and the manhole frame.

It will be noted that non-corrodible metal and bituminous coating are used to preclude corrosion of the flap gates and hinges employed in manholes.

SEWAGE AND SLUDGE PUMPING

By HENRY RYON
Late Senior Engineer
State Department of Public Works, Albany, N. Y.

Part I—Sewage Pumping

During the past several years a very marked improvement has been made in the methods of pumping sewage and sewage sludge, and special pumps have been developed for this service. Only a few years ago, however, practically all sewage was lifted with pumps designed primarily for handling water.

The centrifugal dredging pump driven either by a steam engine or an electric motor was used with a fair degree of success at many stations. While this pump would handle sand and gravel satisfactorily, rags would wrap themselves around the impeller and necessitate frequent cleaning of the pump either through hand holes in the volute or by the removal of the side of the case. It was not very efficient and the head was limited. The smaller and higher speed centrifugal pump, used successfully for pumping water, gave more trouble, due to clogging, when used for pumping sewage, than the dredging pump.

Reciprocating pumps were used in many cases. These pumps clogged about as easily as the centrifugal pumps; and, if there were any sand or grit in the sewage, gave trouble due to the scoring of cylinders. At one or two large stations the crank and fly wheel pump was used and operated satisfactorily principally because of its large size. The ordinary duplex steam pump served in a few cases. The single acting triplex pump, equipped with ball valves, although not entirely free from clogging, proved to be the most satisfactory of the reciprocating pumps and was used, and is still being used, successfully for pumping both sewage and sludge. Its cost is, however, greater than that of a centrifugal pump and it is rather noisy. It is worth noting that the design of the most modern reciprocating sludge pumps have apparently been copied from the old single acting triplex pump.

At almost all of the old pumping stations the sewage was passed through bar or mesh screens to remove the rags and other solids from it before it reached the pumps. The cleaning of the screens always proved a laborious and unpleasant task, and did not entirely do away with the necessity of cleaning the pumps.

The Pneumatic Ejector

In order to eliminate the trouble of cleaning screens and pumps, the pneumatic or compressed air ejector was developed. This device, which was first used about fifty years ago, operates by allowing the sewage to flow into an iron or steel chamber and, when the chamber is full, automatically admits compressed air above the sewage thus forcing it out through the discharge line. The mechanism operates very successfully, and stories are told of ejectors having been lost for several years and when rediscovered were found to be operating satisfactorily. It requires, however, air compressors, air tanks, and other appurtenances which make the first cost and also the maintenance expensive. In addition to this, the efficiency is very low. The overall or wire to water efficiency when the compressors are operated by electricity vary generally from 10 to 20 per cent. At present, due to the improvements in the design of centrifugal pumps, ejectors are being used less and less except in the very small stations or for sludge and screenings handling.

Pump Impellers

The improvement in the centrifugal sewage pumps has been largely in the design of the impellers or runners. There are, in general, two types of pump impellers, the open and the closed. The open impeller gives larger water ways with the same size casing, but solids clog between the impeller and the casing and rags wrap around the impeller blades. Increasing the clearances to reduce clogging, of course, reduces the efficiency and does not prevent rags from stopping the flow. Open impellers, generally with only two blades, serve well in small sump pumps and also in sewage pumps of small capacities where a closed impeller small enough to give the desired capacity would not pass solids of any size. In most cases, however, the closed or semi-enclosed impeller is to be preferred.

In the design of closed impellers for handling sewage, the water passages have been made wider than in water pumps, all sharp edges and turns have been carefully avoided, thus reducing the chance of clogging to a minimum. As a general rule pumps with impellers of this type will pass solids having diameters about one pipe size smaller than the size of the pump. One manufacturer is producing a pump with a worm feed to force the solids to the impeller of the pump and also cut and crush them against hard steel bars running longitudinally of the screw case. Pumps of this type are giving satisfactory service in several western stations. A rather unique impeller is used in some English pumps. The impeller is open on the suction side and the blades are considerably wider at the shaft than at their ends. The edges of the blades pass very close to bars set on the inside of the case and macerate the solids entering the pump.

It is customary to require the impellers of the pumps to be made of bronze but with ordinary sewage there seems to be no advantage in the use of bronze as compared with that of cast iron. A few pumps have been installed having cast iron impellers coated with enamel and they are said to be giving satisfactory results. The manufacturers claim a slightly higher efficiency for this impeller than can be obtained with the bare metal impeller.

Submerged Vertical Pumps

For the smaller installations probably the submerged vertical centrifugal pump is the most commonly used. The sump may be made of cast iron or steel or may be of concrete. The motor and pump are both supported on a removable iron cover so that the pump can be lifted out of the sump for cleaning and repairs. Enough head room must, of course, be provided to allow the suction to clear the top of the sump when the pump is lifted out. It is also desirable that the discharge be brought up through the same plate so that it may be easily disconnected. In unheated pump houses, however, it is sometimes impossible to do this without danger of the sewage in the discharge line freezing. Where short separate discharges can be used, freezing can be avoided by omitting the check valves and allowing the sewage in the discharge pipe to flow back into the sump after each discharge. If screens are to be omitted it is usually advisable to provide a pump not smaller than 3 inches in size. Such a pump will have a capacity of from 50 to 300 gallons per minute, depending upon design of the impeller and the speed of the motor.

Float Controls

Sewage pumps are usually automatic in operation and the arrangement of the float control deserves more attention than it generally receives. The float may be connected to the electric switch either by a push rod or by a chain running over pulleys with a counterweight to balance the float. Either method operates satisfactorily if properly arranged. Floats that hang unprotected in the sump are apt to be moved sideways by the motion of the sewage causing the chain or rod to bind, or the rod to bend, making the float inoperative. In some designs the rod has a guide at the bottom to prevent such motion, but if the rod sticks in the guide or leaves the guide its inaccessible location makes it very difficult to repair. The lever float, sometimes used, has generally proved very unsatisfactory for sewage because rags are apt to collect on the lever and prevent its operation. As in the case just mentioned it is generally very difficult to reach such a float to repair or adjust it. The best design is one in which the float is arranged in a tube to guide and protect it and a removable cover plate provided over the tube so that the float can be readily lifted out.

Pumps in Separate Dry Wells

For the larger pump stations, and even in the small stations when the conditions will permit, the installation of the pumps in a separate dry well makes the most satisfactory arrangement. This leaves the pumps and their appurtenances accessible for repairs and adjustment. The pumps may be either vertical or horizontal. The vertical pumps have the advantage of requiring a smaller pit and of keeping all electrical equipment above ground and free from danger of flooding, while on the other hand the horizontal pumps are easier to keep in adjustment and alignment. If the pit is deep, one or more guide bearings will probably be required on the shafts of vertical pumps as it is necessary to divide the shafts into lengths of not more than 8 or 10 feet to prevent vibration. I-beams are usually set across the pit to carry these bearings, but it is often difficult to set these beams so as to get a perfect alignment of the shaft. In order to avoid this difficulty, several manufacturers are building steel lattice frames extending from the motor to the pump. The pump and motor can then be aligned at the factory with very satisfactory results. In some cases the motor, shaft and pump have been attached to a heavy channel, aligned at the factory, and shipped as a unit.

With the pumps in a separate dry well it will usually be necessary to provide some means for removing seepage from the well. This may be done with a separate automatic sump pump, or, if a cheaper installation is desired, a small valved connection may be made from the suction of one of the main pumps to a sump and the sump emptied at intervals by closing the main suction valve and opening the connection to the sump.

Design of Suction Well

The shape of the bottom of the suction or wet well is of considerable importance. If it is left flat, solids will collect in the bottom and ferment giving rise to unsatisfactory conditions. The floor of the wet well should have a steep slope toward the pump suctions.

In some cases where the sewage is warm and contains considerable grease, trouble has been experienced due to the grease congealing on the walls of the well and then breaking loose in large pieces and entering the pumps and clogging them. The openings in the impellers of 4-inch horizontal sewage pumps have been stopped several times by this cause.

Bearings and Glands

There does not appear to be very much choice in regard to the type of bearings used, ball bearings and sleeve bearings seem to serve equally well provided they are properly oiled. Ball bearings are, however, usually provided to take the thrust or to carry the weight of the impeller of a vertical pump. The part of the shaft that passes through the stuffing box should be of bronze or covered with a bronze sleeve otherwise difficulty will be experienced in keeping the packing in condition. This stuffing box is usually provided with a water seal, although grease seals and special devices are sometimes used. In water pumps the water for the seal is usually taken from the volute of the pump. With sewage pumps, however, this is not advisable for the solids in the sewage are apt to clog the small passages and also because the grit in the sewage will reach the packing and cut the pump shaft. To avoid the possibility of the pollution of the clear water with sewage, the water must usually be taken from a constant level tank supplied from the water lines and not directly from the lines themselves. With double suction and open impeller pumps, if there is a suction lift, there will probably be vacuum on the pump side of the stuffing box and the water seal serves to prevent the entrance of air. With end suction pumps, with enclosed or semi-enclosed impellers, there may be a pressure on the pump side of the stuffing box. The water seal then serves to prevent the grit in the sewage from reaching the packing and cutting the shaft. The pressure on the water seal should of course be greater than the sewage pressure.

Centrifugal sewage pumps will operate satisfactorily if set as high as 15 feet or even a little more above the sewage level, but in such cases special priming devices must be provided for the ordinary method of priming, by filling the suction from the discharge line, cannot be used because it is inadvisable to attach a foot valve to the bottom of the suction. While special priming devices can be used, it is better, if possible, to locate the pumps below the level.

Efficiency and Head

The non-clogging centrifugal pumps will generally give over all efficiencies varying from 35 per cent for the smaller sizes to 65 per cent for the larger pumps. The lift of sewage pumps is usually low and most of the pumps are designed for heads under 40 feet but pumps can be obtained that will lift sewage against heads as high as 75 or even 100 feet. Beyond this head two stages are needed, but the ordinary type of multistage pump used for water cannot be used because of the many sharp turns and the narrowness of the water passages. At a station where it was necessary to raise sewage 180 feet, two pumps connected in series on the same base, with the motor between them, have been used successfully. The overall efficiency of the unit was found on test to be 35 per cent.

Hydraulic Characteristics of Centrifugal Pumps

With centrifugal pumps, careful attention must be given to the hydraulic characteristics of the pumps in designing a pumping station, particularly if the discharge line is of any considerable length.

If an engineer desires a pump to deliver 300 gallons per minute against a head of 20 feet he is very apt to add a little to the head for safety and specify that the pump shall deliver 300 gallons a minute against a head of say 21 feet. A typical 4-inch pump will meet these specifications almost exactly, and will require about 2¼ horsepower to operate it and, a 3-horsepower motor will serve satisfactorily. If, after installation, it is found that the actual head is only 18 feet instead of 21 feet, due to some unforeseen condition or due to the fact that the engineer figured his friction for 10 year old pipe and the pipe is actually new pipe, this pump will deliver 600 gallons per minute instead of 300 gallons per minute and will require 3½ horsepower. The 3-horsepower motor will in that case be overloaded. Conditions similar to this occur very frequently and it is best in all cases to require the motor to be of sufficient size to operate the pump without overheating at any head between the maximum and zero.

When two or more pumps are connected to the same discharge line, the reverse condition often occurs. If two pumps, having the characteristics mentioned above, are connected to a single discharge line, one pump operating alone will discharge 300 gallons per minute. When both pumps are put in operation the friction loss in the discharge line will of course increase. With the particular 4-inch pump just mentioned, if this increase is only about 1½ feet (from 21.0 feet to 22.6 feet) the discharge of each pump will be reduced to 200 gallons a minute or the total discharge of the two pumps will be about 400 gallons per minute or only slightly greater than the discharge of one pump. For this reason it is often found desirable, especially with long discharge lines, to arrange the controls so that one pump will shut off entirely and the second pump, designed for a larger capacity and a little higher head, will start when the sewage flow exceeds the capacity of the first pump.

Multispeed motors are sometimes used to meet these conditions but such motors operate only at certain fixed speeds and it is generally difficult to design the pumps to obtain the desired capacities at these motor speeds. Any desired speed may be obtained by using variable speed motors, but if this is done the losses in the resistances greatly reduce the overall efficiency of the pumping equipment.

At the Harlem Valley State Hospital pumping station which contains 8 4-inch 450 gallon per minute pumps, a special arrangement was used. As each additional pump starts the friction loss in the discharge line increases approximately 6 inches. The controlling float and float switches are so arranged that as each additional pump starts the sewage level in the suction well is automatically allowed to rise 6 inches. Thereby, the total head, and consequently the discharge of each pump, always remains the same and has proved a distinct advantage.

Suction Line Difficulties

There are several matters in connection with the arrangement of centrifugal pump suction lines, particularly where there is some suction lift, which, while they seem very simple, have caused engineers and operators considerable trouble. There must be no high point in any suction line where air or sewage gases may accumulate. When the pump is started the accumulated air will expand, flow to the pump, and stop its operation. The reducer at the pump must for this reason always be an eccentric reducer with the flat side up. Connections to a

common suction header must for the same reason be made at the top of the header and not at the center of the side. In some extreme cases it has even been found necessary to place the suction valves horizontally so as to avoid the accumulation of air in the bonnets. Common suctions, that is, single suction lines to which two or more pumps are connected, are a source of trouble in many cases where there is a suction lift, and wherever possible should be avoided. It is often difficult in such cases to make each pump take its share of the load. When one pump is in operation it is often impossible to start the second without shutting down the first and starting both together. A slight leak in the stuffing box of one of the idle pumps will many times admit enough air to interfere with the operation of the other pumps. Even when the pump that is not to be operated is entirely shut off, air will frequently accumulate in the riser from the common suction to that pump and will expand when the other pump or pumps are started and enter them and prevent them from operating.

Part II—Sludge Pumping

Pumps designed for moving or lifting sewage sludge may, in general, be divided into two distinct classes, displacement pumps and centrifugal pumps. Since these two classes differ radically in their design and operation and present entirely different problems for those in charge of them, it is necessary to consider them separately. The advantages and disadvantages of each class are matters which engineers and operators are not entirely agreed upon. Displacement pumps are unquestionably more easily primed than centrifugal pumps when there is a suction lift and will probably handle small quantities of sludge more readily than centrifugal pumps, but beyond this it is doubtful whether the advocates of either class will admit the superiority of the other.

Displacement Pumps

The modern displacement pumps used for handling sludge are always of the single acting reciprocating type, and are usually electric motor driven plunger pumps having one, two or more cylinders. The makes most commonly used generally have cylinders about ten inches in diameter and strokes adjustable from about two to five inches. The pumps are connected to the motors by gears, belts or chains and the motion transmitted to the pistons by walking beams or eccentrics. Each manufacturer apparently believes that the transmission used by him is the best, but in practice there seems to be little difference.

Transmission

Certain matters in connection with the transmission are, however, of importance. If it is desired to have the pump run smoothly it is usually best to keep the speed of the main pump shaft below about thirty-five revolutions per minute. This gives a piston speed of thirty feet a minute or less, a low figure as compared with the usual figures for water pumps; but the strokes of these sludge pumps are very short and the frequency of the reversals seem to be of more importance than the actual piston speed. Pumps of this type are generally arranged so that the length of the stroke can be changed by shifting an eccentric or, which amounts to the same thing, altering the length of the crank arm. This makes it possible to obtain several different rates of discharge, but experience indicates that the use of the shorter strokes is not always entirely satisfactory. The pumps in most cases do not operate as smoothly with the short strokes as with longer ones, the slip is greater and the efficiency lower. The use of multi-speed motors and variable speed transmissions, although more expensive, afford a more satisfactory and efficient method of changing the pump capacities to suit the conditions, and where available should be used in preference to changing the length of the stroke.

Packing

Like all reciprocating pumps the sludge pumps must be packed to prevent leakage between the pistons and the cylinders, and this packing is one of the most frequent causes of trouble in the operation of the pumps. The packing may be either on the cylinder or the piston Generally it consists of from 4 to 6 rings of ½ inch to ¾ inch packing held in place by an adjustable metal ring or gland. If the packing is too tight, scored pistons or cylinders and broken shear pins will be the result. If the packing is too soft, too loose or improperly placed it will leak, and since the pumps are outside packed this means that the pumps and probably the floor around them will soon be covered with sludge which does not add to the attractiveness of any sewage treatment plant. Opinions differ as to the most satisfactory type of packing. Generally a square braided flax packing serves as well as any. A graphited packing may be desirable to prevent unsatisfactory conditions due to rust where the pumps stand idle for a considerable time. Rawhide packing is satisfactory but does not seem to be necessary except with certain chemicals. The packing must fit and must be properly placed. In cutting the packing it is well to use a template into which a piece of packing exactly the length of one ring can be fitted. In this way each ring will have the same length and the same bevel. The method of oiling the packing varies with the make of the pump. Generally it is found that a fairly heavy oil such as a good grade of cylinder oil gives the best results. Oils known as "500 W" and "Marine Pump Oil" are in common use. A light oil disappears very rapidly. Under continuous operation the packing will usually last about 3 months, but under intermittent operation it may last a year or two. Manufacturers have recently been giving more attention to the finishing of the pistons and cylinders, in some cases grinding them. This has made it easier for operators to keep sludge from leaking between the pistons and cylinders but has not done away with the necessity for careful packing.

Valves

Each cylinder of a reciprocating pump necessarily has an inlet valve and a discharge valve. These valves may be weighted flap valves or ball valves. Each type has its advocates although at present the ball valves seem to be preferred by most operators. Spring loaded poppet valves which operate satisfactorily in water pumps obviously cannot be used for liquids containing an appreciable amount of solids. No mater which type is used the valves will require some attention from the operator. With raw sludge the valves may require cleaning from two to three times a day to two or three times a week. If the pump is handling activated or secondary tank sludge, cleaning will of course be required less frequently. Fibrous material will collect under the hinges or flap valves and rags will accumulate under ball valves holding the valves off their seats and rendering the pump inoperative. Metal flap valves wear at the hinges so that the flap will not seat properly and soon require replacement. Valves of rubber with rubber hinges clog less frequently than metal valves because of their smoother surfaces, but the rubber hinges are inclined to swell and split and it is difficult to turn them back for cleaning. Ball valves are usually of rubber moulded on an iron core. If they are to operate satisfactorily, careful attention must be given to the quality of the rubber, the balance of the valve and the weight of the core. Valves made of a poor quality of rubber will sometimes swell and stick, and cases are on record where the rubber has softened so as to allow the ball to be forced into the piping stopping the pump. The valve must balance or the ball will always seat at the same point and wear rapidly. The weight of the valve must be suitable for the conditions under which it will operate.

Pounding or Knocking

One of the most frequent complaints heard regarding the operation of reciprocating pumps is that they knock or pound. This is due to various causes. Since sludge lines are usually comparatively short, the high water hammer stresses sometimes encountered at water pumping stations are seldom of importance, but the flow of liquid in the suction and discharge lines must be stopped and started with each stroke (single cylinder pump with no air chamber), the valves must close and in doing so strike the seat, and each stroke causes a reversal of stresses in the piston, the crank and the connecting mechanism. These conditions cause pounding which cannot in all cases be entirely eliminated. The subject is too complicated to be discussed in detail here.

The stresses and pounding due to starting and stopping the flow in the discharge line can be generally alleviated by the use of an air chamber, but the air chamber must be large to be of any value. The same thing is true of the suction line, although an air chamber is not so frequently used at this point. One manufacturer provides a small air inlet valve on the suction of the pump which if properly adjusted seems to make the pump operate more smoothly, but of course somewhat reduces its capacity and efficiency.

Valve slam is sometimes due to the fact that the direction of flow through the valve reverses and acquires considerable ve-

locity before the valve closes. This velocity may then carry the valve to its seat rapidly enough to cause a heavy blow when the motion of the valve and the liquid is suddenly stopped. This reverse flow of water through the valve is of course slippage and reduces the efficiency of the pump as well as causing valve slam. The valve should, for these reasons, be heavy enough and so arranged as to close as quickly as possible, and yet not interfere with the operation of the pumper by reducing the area of the ports.

The knocks due to the reversal of stresses in the different parts of a pump are the same as those which occur in any reciprocating machine. If there is any lost motion in a main bearing, eccentric, wrist pin or other part there will be a knock each time the stresses are reversed. The remedy is obvious. All bearings must be properly adjusted and kept properly lubricated.

Centrifugal Pumps

Centrifugal pumps, if they are to handle sludge successfully, must pass solids without frequent clogging. This makes it necessary to use end suction pumps at least 4 inches in size with as few bends and sharp corners in the liquid passages as possible. The impellers usually have only two blades with long sweeping curves and are either fully enclosed or have a shroud on one side. Open impellers clog very rapidly when the liquid contains rags. Even with these precautions, it is generally desirable to have hand holes or other means of access to the interoir.

One pump manufacturing company equips its centrifugal sludge pumps with a screw to force the sludge into the pump and to macerate the solids as they enter. Pumps of this type have been in operation at a number of plants for several years. Similar devices are being made by some other manufacturers but have not as yet come into extensive use.

Capacity and Regulation

A 4-inch centrifugal pump will readily discharge 100 gallons a minute and in some cases as low as 50 gallons a minute, but if capacities below this are necessary some difficulty is apt to be experienced unless provision is made for reducing the speed below that which can be obtained by a direct connected motor. Variations in head, of course, cause variations in the capacity of a centrifugal pump and if a definite quantity of discharge is required some method must be provided to compensate for these variations. In many plants it is necessary to change the quantity of sludge delivered from time to time and provision must be made for so doing. Theoretically, throttling might accomplish these ends, but throttling is not desirable when pumping sludge. If careful adjustment of the quantity of sludge delivered is necessary the only practical method of regulations seem to be to change the speed of the pump. Variable and multi-speed motors will do this within limits but are not as satisfactory as some of the variable speed transmissions available. These transmissions, while expensive, make it possible to obtain almost any capacity within the limits of the pumps. It must not be forgotten, however, that a centrifugal pump will give its highest efficiency at one definite speed and capacity and that as the speed and capacity are changed the efficiency may fall off rapidly. This is naturally of more importance when the pumps are in continuous operation than when they are operated intermittently.

Priming and Seals

Centrifugal pumps will not handle air and when they are used careful consideration must always be given to priming and to the elimination of air pockets in the suction line. To facilitate priming, centrifugal pumps should if possible be set below the surface of the liquid in the suction well. If the pump must be set above the level of the liquid some means of priming must be provided. Foot valves which are often used with water pumps will not serve satisfactorily with pumps handling sludge. Vacuum systems are available and operate satisfactorily if kept in condition, but mean added expense of installation and more equipment for the operator to maintain.

The impeller shaft of every pump of this kind must pass through the pump casing and therefore requires a stuffing box to prevent leakage. On water pumps these stuffing boxes are provided with water seals and the water taken from the pumps. The material handled by a sludge pump is not, however, suitable for the seals and water must be obtained from some source. A direct connection to the water system cannot be used due to the danger of polluting the water supply with sludge. If the building is high enough a small tank fed over the top and controlled by a float valve may be used as a source of water. The height of the tank must be greater than the discharge head of pump or the sludge will be forced into the packing and probably result in the scoring of the shaft. If the tank cannot be set high enough, a small pump may be used to supply water to the seal. Grease seals and other special devices are sometimes used but are not as satisfactory as water seals.

POWER AND HEAT EQUIVALENTS

1 horsepower-hour = 0.746 kilowatt-hour = 1,980,000 foot-pounds = 2550 B. T. U. (British thermal units) = 2.64 pounds of water evaporated at 212° F. = 17 pounds of water raised from 62° to 212° F.

1 kilowatt-hour = 1000 watt-hours = 1.34 horsepower-hour = 2,653,200 foot-pounds = 3,600,000 joules = 3420 B. T. U. = 3.54 pounds of water evaporated at 212° F. = 22.8 pounds of water raised from 62° to 212° F.

1 horsepower = 746 watts = 0.746 kilowatt = 33,000 foot-pounds per minute = 550 foot-pounds per second = 2550 B. T. U. per hour = 42.5 B. T. U. per minute = 0.71 B. T. U. per second = 2.64 pounds of water evaporated per hour at 212° F.

1 kilowatt = 1000 watts = 1.34 horsepower = 2,653,200 foot-pounds per hour = 44,220 foot-pounds per minute = 737 foot-pounds per second = 3420 B. T. U. per hour = 57 B. T. U. per minute = 0.95 B. T. U. per second = 3.54 pounds of water evaporated per hour at 212° F.

1 watt = 1 joule per second = 0.00134 horsepower = 0.001 kilowatt = 3.42 B. T. U. per hour = 44.22 foot-pounds per minute = 0.74 foot-pounds per second = 0.0035 pounds of water evaporated per hour at 212° F.

1 B. T. U. (British thermal unit) = 1052 watt-seconds = 778 foot-pounds = 0.252 calorie = 0.000292 kilowatt-hour = 0.000391 horsepower-hour = 0.00104 pounds of water evaporated at 212° F.

1 foot-pound = 1.36 joule = 0.000000377 kilowatt-hour = 0.00129 B. T. U. = 0.0000005 horsepower-hour.

1 joule = 1 watt-second = .000000278 kilowatt-hour = 0.00095 B. T. U. = 0.74 foot-pound.

EQUIVALENTS OF OUNCES IN WATER AND MERCURY

Ounces	Inches of Water	Inches of Mercury	Ounces	Inches of Water	Inches of Mercury
.3	.521	.038	8	13.9	1.020
.576	1.0	.073	9	15.6	1.148
1	1.7	.128	10	17.4	1.275
2	3.5	.255	11	19.1	1.403
3	5.2	.383	12	20.8	1.530
4	6.9	.510	13	22.6	1.658
5	8.7	.638	14	24.3	1.785
6	10.4	.765	15	26.3	1.913
7	12.2	.893	16	27.8	2.036

MAINTENANCE OF SEWAGE PUMPING STATIONS

By A. L. SODEN
Chief Operator
Sewage Treatment Works, Trenton, N. J.

THE writer, after some fifteen years of experience with seven pumping stations containing twenty-seven pumps with capacities from 50,000 to 11,000,000 gallons per day, has come to the very definite conclusion that maintenance of this type of equipment involves three main objectives, proper lubrication, cleanliness, and frequent detailed inspection. At first thought the first two involve the last, but dumping oil or grease into a machine plus wiping it off do not constitute inspection any more than feeding and bathing a baby is a substitute for a doctor's periodic checkup. The point I wish to drive home is that good maintenance catches trouble *before it starts* and postpones indefinitely the day when the machine must be scrapped for any other reason than obsolescence.

The use of good oil and grease is a very essential item. Lubricants not suited for each particular piece of equipment may, however, no matter what they cost, do more damage than a cheap oil of a suitable character. It must be kept in mind that too much oil in many cases tends to cause more wear than too little, due to the fact that dust, always present in the air, will mix with the oil and act as an abrasive when passing through the bearings. This situation is more serious in a gravity or pressure feed system than with the oil reservoir type.

It is axiomatic that efficient lubrication is a matter of using good lubricants, properly selected, in the correct quantity, at the right intervals. Neglect or omission of any of these factors means accelerated depreciation and breakdown.

Low Price—High Cost Lubricants

Cheap lubricants are costly in the long run and if the average operator would only sit down and figure the total saving per year in a few cents less per quart of oil, or pound of grease, as against many dollars for new bearings, sleeves and shafting, damaged by cheap "bargain" goods he would realize that the best is none too good. We had an example of this in Trenton where for a time the purchasing department paid twenty-seven cents per gallon for automobile oil which was bought on a price basis.

Even though good materials are supplied, one must be certain that they are of the right weight, viscosity, etc., for the job and the only way to be certain is to follow the manufacturer's recommendation for the unit being serviced, or, if this is not available, call in a lubrication engineer from one of the big companies. You will note the word "engineer"—beware of smooth talking salesmen with trick oils that never wear out, made by some magical process and sold at high prices under a fancy name.

It may seem proper to the average person that as long as the correct amount of oil or grease is in a bearing and no noise or heat is noticeable that the machine could run indefinitely. This, however, is *not* true as many pieces of equipment are installed in damp wells where condensation is present, the worst enemy of any bearing no matter what type lubrication is used.

Gravity or pressure feed lubrication systems with an oil filter in the line do not require as much attention as equipment having the oil reservoir. A good method to follow is draining and flushing these types of bearings and refilling with new oil at least every six months, and in some instances where water is present, every three months.

Shaft Bearings

Many line shaft bearings are made for grease lubrication and can be run with safety on equipment in small booster stations for about a year before flushing and repacking with new grease. We have found through past experience that it is sound economy to remove the bearings from the shafts and wash thoroughly in gasoline or kerosene, both the bearings and the oil reservoirs, thus removing all traces of moisture, old grease and foreign matter at least once a year. This procedure should be more frequent in a plant where the equipment is running continuously. Care should be taken to put the right amount of grease in a bearing as too much causes bearings to heat through increased friction.

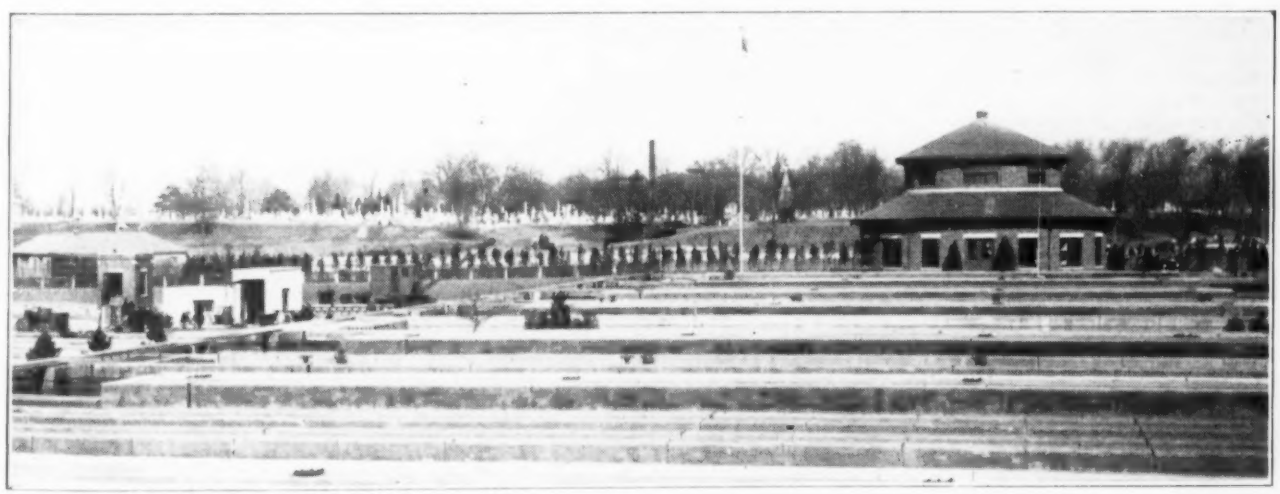
An oil filter, if used, should have at least twice the capacity of the lubricating system. This unit is used to separate the water and oil in a primary chamber and, in a secondary compartment, dirt in the oil which has a tendency to collect in bearing boxes, and any scaling which may develop in the oil lines. Such is particularly true if the latter are constructed of iron or steel pipe and fittings. Copper tubing or brass pipe and fittings are the only materials which should be used, thus preventing damage to bearings due to the stoppage of the oil grooves by pieces of rust or scale which come from iron or steel pipe, even though these be galvanized.

The matter of cleanliness around any machinery is a very important factor not only for looks but for the good of the equipment. It must be kept in mind that next to water, dust and dirt are the most destructive enemies to motors, bearings, controllers, starting switches, and many other pieces of electrical equipment that are found in a pumping station.

Motor Care

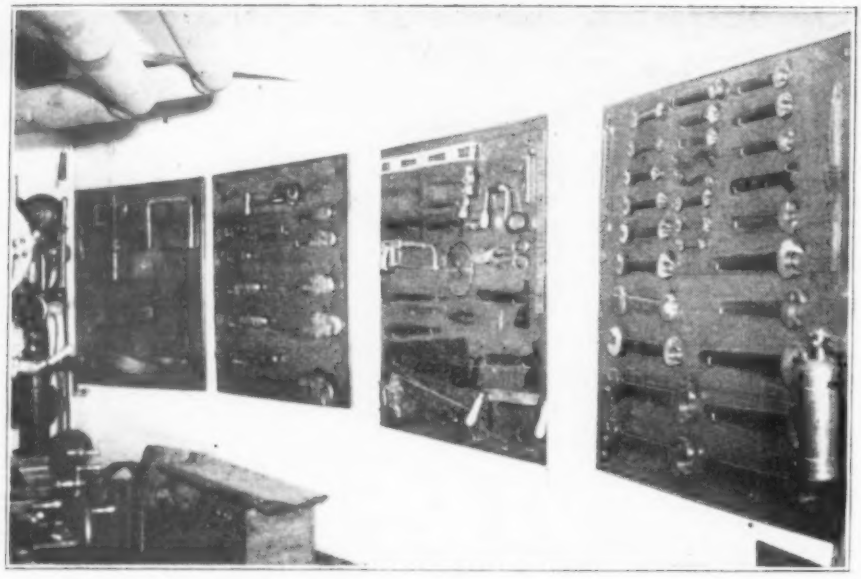
Motors must be kept free from water, oil and dirt. A good method of cleaning the interior is with compressed air or a bellows. When using compressed air care must be taken to be certain there is no moisture in the storage tank that could escape through the nozzle used for cleaning. Cleaning motors with compressed air should never be done by an amateur. The older the motor the more brittle the insulation and high pressure air through too small a nozzle can be very destructive to the motor insulation.

An excellent plan is to give the motors a thorough cleaning once every six months and at least once every two years give the windings a coat of a good grade of insulating varnish. At this time the bearings should be thoroughly cleaned and refilled with new oil, or repacked with new grease.



The Treatment Works of Trenton

One Battery of Imhoff Tanks and Pumping Station



Shop and Tool Room of the Main Pumping Station—Trenton, N. J.

Contactors

Contactors often give an operator more or less trouble due to particles of dust becoming imbedded in the contact fingers. It is a good plan never to use any lubricant on the main contact tips which are mostly constructed of copper, as oil or grease has a tendency to shorten the life of these items. If they should become pitted or burned, which in many cases cannot be avoided, remove the contact tips and clean up with a smooth file or very fine sand paper. Care should be taken when attempting to clean contacts in place not to bend or misalign the parts.

If the operating force is large enough it is a good policy to assign different parts of the equipment and pumping station to the shift operator or oilers and set up a system whereby the entire equipment and pumping station is cleaned at least once every month from top to bottom, besides the daily routine sweeping, mopping and dusting.

Insurance in Cleanliness

This, however, does not mean that the equipment should be dismantled and reassembled but it is important to get the dust and dirt, which is on the surface, before it has a chance to penetrate to the vital parts of the machinery. It will not work a hardship on any member of the operating force to do a little cleaning now and then, no matter what the title of the job he holds. By doing this a man gets around and has a chance to inspect parts of the equipment which he otherwise would not give a second glance unless trouble should develop in that particular spot.

To be clean is to be free from dirt, odor and keep tidy. There is no reason why a pumping station should not be kept clean, no matter what type—water or sewage. A little attention to cleanliness will result in continued satisfactory operating results and enable the operator to get the most efficient results and best service out of the equipment for many years.

Thoroughness

Maintenance of any piece of equipment should be as thorough as a doctor's examination, not just the usual haphazard method of looking or just glancing in the direction of the machinery. A system of inspection should be drawn up and followed to the letter.

Commutators and Brushes

Detailed inspection of motors, shafting, electrical equipment, pumps and piping should be done by men qualified through years of experience for they know what to look for in each unit.

In the case of single phase motors, commutators become rough and burned through continuous operation, dust and oil accumulating being the chief cause. Commutators should be polished with sand paper on a flat block of wood so that the insulation between the segments will be cut back even with the copper. Under no circumstances use emery cloth or emery paper in this operation. A commutator hone with the correct radius is the most efficient tool to use for this purpose.

The brushes should move freely in the brush holders, with the proper spring tension as recommended by the manufacturer. If they do not move freely, a good contact with the commutator will not be made during the starting period. Both brushes and brush holders should be inspected periodically to see that the brushes have not worn down to a point where they are so short that the brush holder springs cannot press the brushes against the commutator, thus causing burning of the brushes and commutator through arcing.

Motor-cleaning

It is a good policy in the case of single phase motors, having a short-circuiting device, to overhaul once every year. Motors of this type are hard to clean if not dismantled and every part thoroughly washed. There should never be any trouble at this point except for an abnormal accumulation of dirt or frequent overloads in excess of the maximum capacity of the motor.

The normal running temperature of an electric motor is considered a few degrees above the room temperature and should never be allowed to exceed the general standard of forty degrees centigrade above surrounding atmosphere. Motors will carry a full load continuously with no cause for concern if the room is well ventilated. Overloads or undue friction in the bearings will cause the temperature to rise and should be investigated immediately to remedy the trouble.

Motors of different sizes have their own peculiar sound when running, so an operator after a time will become accustomed to this sound and should any noise not characteristic to the motor develop, he will immediately detect it and look for the trouble and remedy it before any damage has been done.

Shafting and Bearings

Shafting in any plant requires attention more often than other parts of the equipment, to insure the longest possible life of the shaft and the shaft bearings. Shaft alignment may be as true as it is humanly possible to make it, but it will not necessarily stay aligned. A bearing wearing due to friction may cause a slight whip in the shaft and be transmitted to the other shaft bearings, thereby causing added play from vibration. A periodic check of the shaft alignment is most advisable.

Bearings on any shafting should be painted a light color, so when a bearing gathers too much heat the paint will discolor and can be detected immediately Many plants have a thermal overload device which stops the unit when too much heat develops in any shaft bearing. The operator must go to the bearing indicaated on the panel and reset the overload switch before the machine can be started again.

In plants which do not have such a device to depend on an operator must go to each bearing and rely on his sense of feeling, even this method will not tell the true story. A thermometer should be used in any and all cases where there is a suspicion of too much heat. Generally after a bearing has carried excessive heat it is too late even for a thermometer, instead a new bearing is indicated, this being true where periodic inspection is deficient.

When a shaft bearing becomes worn, no matter how little it is false economy to leave it in service. Worn shafting will vibrate and promote undue wear on both motor and pump bearings where direct connected. A bearing in this instance would be cheaper to replace than try to get by with, as possibly a whole section of shaft or motor and pump bearings will be ruined in a short time.

In stations that are automatically controlled by float or pressure switches and no attendant is on duty any length of time, it is advisable to paint the shafting to protect it against rusting. No metal will gather rust more quickly than a highly polished piece of steel. By doing this the unit can be wiped off and be kept clean.

Polished shafting should never be cleaned while the machine is in operation. Although a much better job can be done it is a very dangerous practice. Use of emery cloth should be avoided as the residue may enter the shaft bearing boxes and cause trouble. A good cleaning with soap and water and polishing with metal cleaner will give the best results and not endanger the man doing the cleaning.

It is very important to have uninterrupted operation in many

plants, where no standby units are installed. In case of power failure sufficient emergency lights should be available and special jumpers made up for continuous operation in case of burned out starters, float switches, etc.

Emergency Wiring

Rubber covered elevator cable is the most desirable material for emergency wiring, using copper lugs at either end of each wire. This will simplify connecting to the motor and main or branch switches, thereby removing from service the broken starter or float switch. Manual control will be necessary in the case where the float switch is not working. The size of the wire used for jumpers depends upon the size of the motor. This, however can only be applied to small low voltage motors of the "across the line" type. In case of large motors such as 50 HP, 2,300 volt, consult an electrical engineer for advice.

Pump Care

Necessary tools and equipment should be on hand in case of pump failure due to clogged impellers or any overload which would cause fuses to burn out or overload switches to kick out. Any pump being overloaded can be detected by the sudden rise of the ammeter.

Wearing rings in the pump case and on the impeller should be checked occasionally for clearance by using a thickness gauge. Install new rings when the gap has become large enough to impair the efficiency of the pump. New rings installed will improve the pumping capacity, thereby effecting a saving in the electric power consumption.

Packing Pointers

A most important factor, one which can cause much annoyance to the operator and plenty of damage to a pump is the proper size and grade of packing. For pumps handling dirty water—sand and grit—a packing should be selected with some thirty-five per cent lubrication, thus saving the sleeves from being worn too quickly and excessive seepage at the stuffing boxes. No gland should ever be pulled down with a wrench except at such times as to effect the proper seating when new packing is installed. Stuffing box gland nuts should never be more than finger tight, as too tight a packing will cause a braking effect on the pump shaft thereby overloading the motor.

Care should be taken when repacking any piece of machinery to see that the strands do not twist while being forced to the bottom of the stuffing box. Never under any circumstance use more packing in a stuffing box than is absolutely necessary to keep the pump from leaking at this point.

Consult a packing engineer if in doubt as to what grade of packing the unit may require. Experimenting with packing in a pump sometimes is very costly.

The piping in most instances will require little or no attention other than caulking a few leaks that may develop, or removing clogging material which can readily be detected by the use of an ordinary steam pressure gauge. A sudden rise of the gauge when connected to the force main will indicate clogging. It is of course necessary to know the normal reading for comparison.

Check Valves

Check valves should be inspected at least once every six months, including internal parts. At this time the seats, clapper faces, and whole interior can be thoroughly cleaned. At more frequent intervals test valves for tightness. Manila paper should be used for the cover gasket after being well oiled with machine oil before installing.

The building housing the equipment must be maintained as well as the machinery. The roof must be kept in constant repair so there is no possibility of water leaking through on the electrical apparatus thereby causing untold damage. Floors should be painted and rubber matting placed thereon at points in front and rear of the switchboard to protect the operator and on the floor where traffic is the heaviest, for appearance. Walls in the dry well should be inspected and repaired when necessary to prevent any seepage of sewage or ground water.

All wood work in the entire building should be painted or varnished at least every two years to protect against dampness, also to keep the appearance of the station up to par. Costly repairs may be caused by neglecting any part of the building.

Tools

It must be understood that no person can do repair work without the proper tools. A suggested list of tools to be included along with those supplied by the pump manufacturer are:

Tool List

Socket Wrench Set (sizes 7/16" to 1⅛" inclusive).
Pliers—2 pair (1—slip joint; 1—side cutting).
Screw Drivers—set of 3 (3, 4 and 6 in. blades).
Stillson Wrenches—two (one 10" and one 18").
Hammer (machinist's, 2 pound).
Oil Cans—3 or 4 (spout oilers, plainly marked as to contents).
Putty Knife (for scraping old gaskets from pump casings).
Thickness Gauge (for spacing and setting couplings and checking clearances of pump rings).
Packing Tools—full set for removing and replacing packings in stuffing boxes).
Assorted Packings (of pump mfgr's recommendation).
Spirit Level (machinist's level of dependable make).
Fuse Puller.
Voltage Tester.

Too many so-called mechanics of the Stillson wrench type do more damage to machinery attempting an overhaul job than several years of wear and tear, to which the machine is subject. A plant of any size should have among the personnel, men capable of doing all minor and most major repairs, thereby effecting a substantial saving in a year's time over hiring outside mechanics or specialty men to come in and make these repairs.

Spare Parts

Adequate spare parts should be kept on hand at all times to replace worn out or broken parts of the equipment, thus saving time. In many cases a unit may be out of service several days waiting for some part whose initial cost may be less than $5.00. Of course, it would be practically impossible to keep enough spare parts on hand to cover the entire equipment. However, essential parts: such as holding coils for contactors likely to burn out any time, and such parts that have to be made up special at the factory, taking 10 to 30 days for delivery, should be stocked.

A most important item in the operation of a plant is the budget. No matter how well the equipment is maintained, normal wear and depreciation must be taken care of. It is false economy to repair only one part of the machine and not replace all the worn parts, just to save a few dollars temporarily.

The old cry is heard many times about effecting economy by using drastic and scientific measures which look very good on paper but in general practice are not worth a second thought, compared to the cost that is likely to be involved by delaying necessary repairs.

Value of Record Keeping

Keeping records of plant operation is an important factor. Although at the time of recording the data compiled may not seem to be of any significance, it later can be used as a reference for comparing the upkeep, electrical energy required by the different units and depreciation. An excellent method to follow is the frequent reading at stated intervals of all instruments and gauges on the units that are operating, making notations from time to time of any adjustments together with the routine work as required of an operator while on duty. Daily tabulation of all charts and logs will readily tell the story of how the plant is operating—normally or otherwise. At the end of each month the daily tabulations can be set up in the form of a monthly report, showing for example, amount of rainfall, daily pumping average, daily maximum and minimum flow, amount of screenings and grit removed, and amount of sludge removed from different tanks.

The above data can easily be transformed into a yearly report going into more detail if necessary to show the cost of pumping and treating the sewage.

In conclusion, an operator without the aid of expensive testing instruments can readily operate a plant by using some degree of intelligence and the better known common sense. His natal equipment of eyes, ears, nose and sense of touch are all invaluable aids provided, of course, that his head is something better than a hatrack.

IMPROVED METHOD OF VELOCITY CONTROL IN GRIT CHAMBERS

By RALPH J. BUSHEE, Designing Engineer
Chas. W. Cole & Son, South Bend, Ind.

Part I—Method of Velocity Control

THE problem of designing a grit chamber with a control section that will give a constant velocity at all flows is essentially that of making the shape of the depth versus cross-sectional area curve of the grit chamber fit the depth versus quantity/velocity curve of the control section. The earlier approach to this problem consisted in the development of the so-called proportional weir, which had a straight line depth-quantity characteristic as is needed with grit chambers of rectangular cross-section. While the velocity control obtained by this method has been satisfactory, there is a disadvantage in that for proper operation of the weir, the entire head in the grit chamber must be lost.

In order to make use of control sections, such as the Parshall and Venturi flumes, which require a smaller loss of head for their operation, Camp[1] and Holmes[2] have proposed that the shape of the grit chamber be adapted to fit the head-quantity curve of the control section. By this method it is possible to reduce the loss of the head to as little as one third of the depth of flow in the grit chamber. The disadvantage of this method is that the resulting cross section is not the most economical one to build, and moreover, it is not well adapted for most mechanical cleaning mechanisms. The slope of the side walls may be quite flat in some cases. Barker[3] has suggested that this last difficulty could be solved by building two or more chambers for one control section.

A Proposed Method

There is, however, a third solution to this problem which makes it possible to use a grit chamber with a rectangular cross section in conjunction with a flume, or any other control section for that matter, and still get a velocity which is very close to that desired over a wide range of flows.

This method consists essentially in determining the relationships so that the straight line depth versus cross-sectional area curve of the rectangular grit chamber lies as closely as possible to the depth versus quantity/velocity curve of the control section, over the range of flows being considered. To accomplish this, two relationships must be determined; first, the ratio of the width of the grit chamber to the width of the control section which gives the closest average slope of the two curves; and secondly, the relative elevations of the bottoms of the control section and of the grit chamber which result in the closest position of the two curves. The determination of these two relationships can best be made graphically and the curves of Fig. 1 are used for the solution with a free-flowing venturi flume. It will be understood that the method is perfectly general and can be used for any type of control section for which a curve can be drawn.

A Specific Example

The formula for the flow through a rectangular free-flowing Venturi flume is

$$(1)\quad Q \equiv 3.09\ b\ H^{3/2}$$

where "Q" is the flow in second feet, "b" is the width of the flume in feet, and "H" is the total energy head (depth plus velocity head) above the flume.

The middle curve in Fig. 1 is for the above formula with $b = 1.0$. In order to be able to determine the velocity limits within which we are working, curves of 0.95 Q and 1.05 Q are also shown.

As an example, assume a grit chamber 4 feet wide with a maximum capacity of 8 m.g.d. or 12 sec.-ft. At 1 foot per second velocity the depth at maximum flow would be 3 feet. Lay a triangle tangent to the lower curve and at such an angle that the difference in ordinates between the point where the edge of the triangle cuts the OY axis and the point where it intersects the upper curve is 3 feet. The point where the straight edge cuts the OY axis, in this case 0.62 feet, is the distance that the bottom of the flume must be below the bottom of the grit chamber.

To determine the required width of the control section, draw a line through the zero point parallel to the above line. A point on this line is $E = 1.0$ and $Q/b = 6.7$. Thus with a foot in the grit chamber, corresponding to 1.62 feet total energy head on the flume, a flume 1 foot wide will pass 6.7 sec.-ft. Since the amount required for the assumed grit chamber 4 feet wide is 4.0 sec.-ft., the width of the flume should be 4.0/6.7 of 1 foot or 0.597 foot, or 7.15 inches. It will be noted that between depths of 0.4 and 3.0 feet in the grit chamber (heads of 1.0 and 3.6 on the flume), corresponding to flows between 1.1 and 8.0 m.g.d., the theoretical velocity through the grit chamber will be between 0.95 and 1.05 feet per second. This range of flows, with the maximum of seven times the minimum, is sufficient for most conditions.

Correction for Fillets

Most grit chambers have fillets at the bottom. With hand cleaned grit chambers this allows the cross-baffles, or other means of demarcation of the grit storage space, to be removed for the manual cleaning of the chambers. With mechanically cleaned chambers it allows the installation of cleaning devices with scrapers or buckets shorter than the width of the chamber. Where such sloping sections are installed it is merely necessary to maintain the total cross sectional area of the grit chamber below the top of the fillets.

Thus in Fig. 2 the areas omitted (1 + 2) must be equal to (3), the area added. The cross-sectional area of the original grit chamber below the top of the proposed fillets is $b \times d$. The area of the new section below the same line is $ab - ac = a(b - c)$. Equating these and solving for $(a - d)$, which is the distance that the bottom of the new section must be lowered, we obtain

$$(a - d) = \frac{ac}{b}$$

Returning to the example employed, suppose that it is desired to install fillets 0.75 foot wide (c) and 1.0 high (a). Then it will be necessary to lower the bottom of the grit chamber in respect to the bottom of the flume by $\frac{0.75 \times 1.0}{4.0} = 0.19$ foot. And the bottom of the control section will be $0.62 - 0.19 = 0.43$ foot below the bottom of the grit chamber.

After the control section has been determined, it is well to check the design computations to see what velocity may be expected.

Table 1
Velocities Through Grit Chamber

Flume		Grit Chamber		
Total Head, Ft.	Flow, Sec.-Ft.	Water Depth, Ft.	Cross Section Area Sq. Ft.	Velocity, Ft./Sec.
0.93	1.79	0.50	1.44	1.24
1.43	3.16	1.0	3.25	0.97
1.93	5.09	1.5	5.25	0.97
2.43	7.05	2.0	7.25	0.97
2.93	9.32	2.5	9.25	1.01
3.43	11.9	3.0	11.25	1.03

Note that the introduction of fillets has increased the velocity at the 0.5-foot depth in the grit chamber. Without fillets the velocity at this depth would have been 1.08 feet per second. However, the results are close enough for this case, and in cases where they are not, the design can usually be improved with a little cut and try.

Part II—The Control Section

Sections Considered

Theoretically, any control section for which a head flow curve can be drawn can be used with the above method. From the standpoint of construction, however, the Parshall and the rectangular Venturi flumes offer advantages.

The Parshall flume would at first sight appear to be the ideal section to use, as it has a solid background of experimental data, and is made with plane surfaces which permit of easy construction. Unfortunately, however, the maximum depths commonly used in the design of grit chambers are beyond the range of the experimental data available for Parshall flumes. There is also some difficulty in interpolating smaller sizes of Parshall flumes which are of somewhat different shapes. This difficulty could be solved by making the width of the grit chamber correspond to that of one of the standard flumes.

If a Parshall flume is used, it is to be noted that the head

given in the formula is not the total head above the flume, as in some cases the velocity head at the point of measurement is a considerable proportion of the total head.

Free Flowing Venturi Flume

Where there is sufficient loss through a Venturi flume to allow it to occur, the quantity passed by the flume will be the maximum possible for the total head available. The flume is then said to be free flowing and formula (1) will apply. In general, free flowing conditions may be assumed in a Venturi flume when the loss of head is not less than one-third of the total head above the flume. The formula is a rational one and is obtained as follows:

$$(2)\ Q = bd_t V_t$$

$$(3)\ d_t + \frac{V_t^2}{2g} = H$$

(by Bernoulli's theorum neglecting friction)

Where Q, H and b are as previously given, and d_t and V_t are depth and velocity respectively at throat of flume.

Solve for V_t in (3); substitute it in (2); solve for dQ/dd_t, and equating it to zero, derive $d_t = \frac{2H}{3}$

as the condition giving the maximum value of Q.

Substituting 2/3 for d_t in (2) and (3), solving for V_t in (3) and substituting in (2) gives

$$(4)\ Q = \frac{2}{3}\left(\frac{2g}{3}\right)^{1/2} bH^{3/2} = 3.09\, b\, H^{3/2}$$

It is reasonable to suppose that the shortest possible transition section ahead of the throat which would avoid a too abrupt change in flow conditions would be the one in which the slope of the water surface was uniform.

In addition to the definiations given above, let "mb" equal the width at a section at a distance of "nL" above the throat, "h" the water depth at this section, and "L" the length of the section between the grit chamber and the throat of the flume (Fig. 3).

$$\text{Then (5)}\ h = 2/3H + 1/3H\frac{nL}{L}$$

$$= \frac{H}{3}(2+n)$$

$$(6)\ H = h + \frac{v^2}{2g}$$

$$(7)\ V^2 = \frac{Q^2}{m^2 b^2 h^2}$$

and (4) $Q = 2/3\ (2/3g)^{1/2} bH^{3/2}$

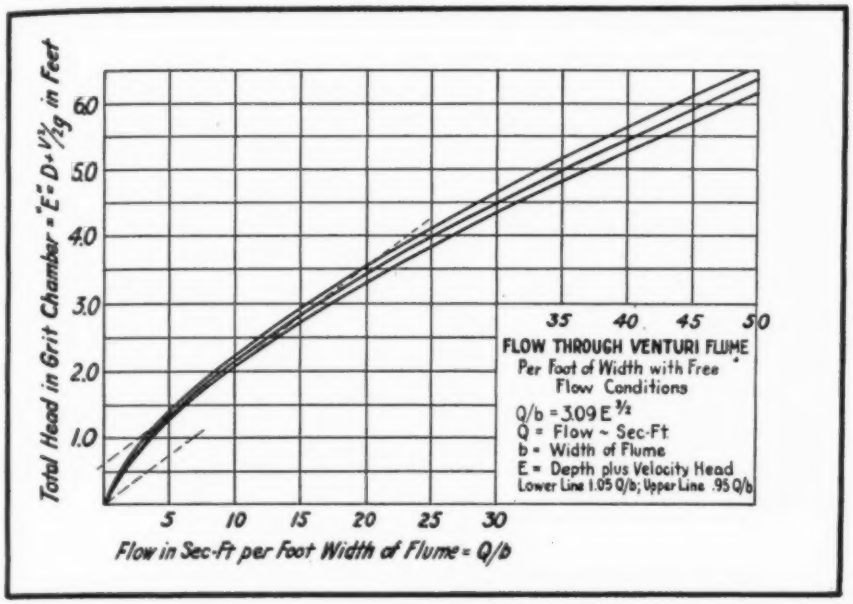


Fig. 1—Flows per Foot of Width of The Venturi Flume for Various Heads.

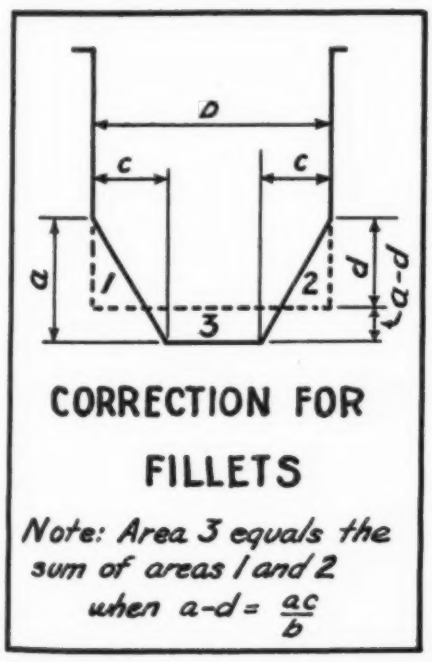


Fig. 2—Method of Correcting for Fillets in Design.

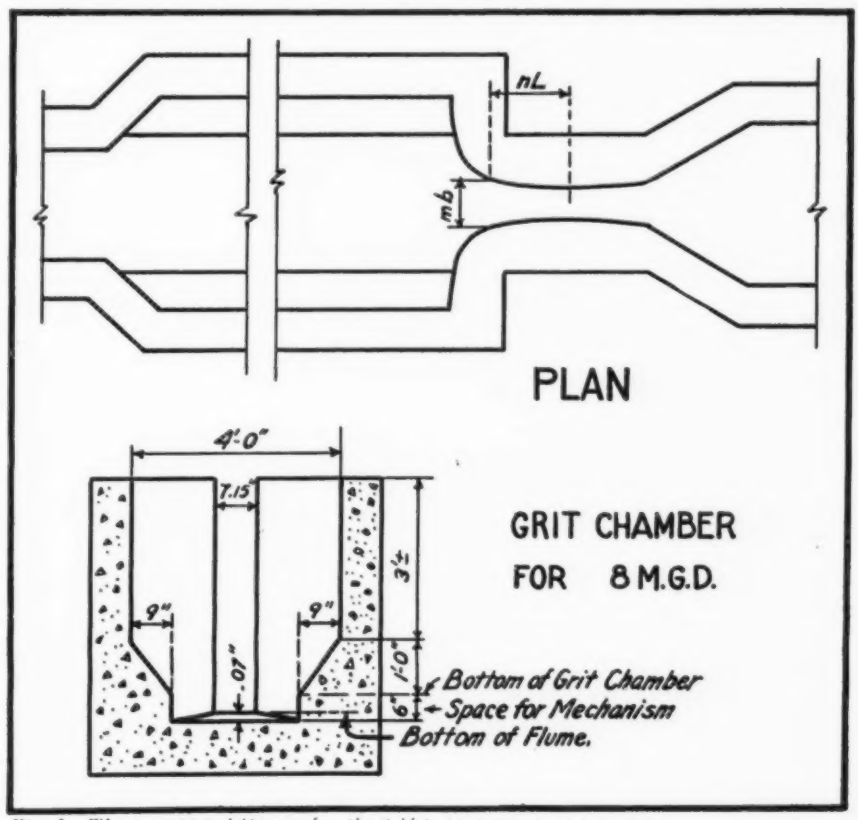


Fig. 3—The Completed Design for the 8 M.G.D. Example Section.

Substitute these values of h, V and Q in equation (6) and the equation reduces to

$$(8)\ m = \frac{2}{(1-n)^{1/2}(2+n)}$$

The following table gives the relationship expressed in the above formula:

TABLE 2

Factors for Designing a Flume with Uniform Slope of Water Surface

n = Factor for Distance Above Throat	M = Factor for Width of Section
0	1.0
0.1	1.005
0.2	1.02
0.3	1.04
0.4	1.08
0.5	1.13
0.6	1.22
0.7	1.35
0.8	1.60
0.9	2.18
1.0	∞

Returning to the example employed, suppose we assume that the length of the transition section will be the equal to two-thirds of the maximum assumed depth of flow, or 24 inches. This will correspond to a maximum water surface slope of 3 to 1, as the depth at the throat will be two-thirds the head in the grit chamber. Also assume a length of throat of 0.2 of the depth, or 7.2 inches. Assume the return section with the same 3 to 1 surface slope. Then, since the minimum loss of head that we have assumed is equal to the velocity head at the throat section, it does not appear necessary to be concerned with the recovery of this velocity head. Make the return section 18 inches long, which allows for a theoretical recovery of 50 per cent of the velocity head. The total length of the control section is then 24 + 7.2 + 18 or 49.2 inches. Using the above table and the established throat width of 7.15 inches, we obtain a flume of the following shape. The width has been divided by 0.97 to allow for friction loss ahead of the throat.

TABLE 3

Design of Control Section

Distance from Grit Chamber, Ins.	Factor n	Factor m	Width of Section = 7.15 m/.97 Ins.
2.4	0.9	2.18	16.2
4.8	0.8	1.60	11.8
7.2	0.7	1.35	9.9
9.6	0.6	1.22	9.0
12.0	0.5	1.13	8.3
14.4	0.4	1.08	7.9
16.8	0.3	1.04	7.7
19.2	0.2	1.02	7.5
21.6	0.1	1.005	7.4
24.0	0.0	1.0	7.4
27.6	0.0	1.0	7.4
31.2	0.0	1.0	7.4
34.8	0.1	1.005	7.4
38.4	0.2	1.02	7.5
42.0	0.3	1.04	7.7
45.6	0.4	1.08	8.0
49.2	0.5	1.13	8.3

Figure 3 shows the outline of the finished design. It is, of course, not essential that the flume be made with curved sides as shown. This design appears to make for the shortest possible length of control section. If straight sides are used, the approach section ahead of the throat should be longer. It is necessary that the throat be of sufficient length so that the free-flowing condition is well established.

References

1. Camp, U. S. Patent.
2. Holmes Water Works & Sewerage, May, 1933.
3. Barker, Water Works & Sewerage, April, 1939.

DESIGN OF CONTROL FLUMES FOR GRIT CHAMBERS

Simple Aid for Use With the Bushee Method

By W. E. HOWLAND

Prof. of Sanitary Engineering, Purdue University, Lafayette, Ind.

IN the above article entitled "An improved Method of Velocity Control in Grit Chambers," by R. J. Bushee, the use of the Venturi flume for this purpose is suggested, and a satisfactory graphical method of design is fully described.

Herein are offered without derivation (1)a formula which shows conveniently the departures from a standard velocity of one foot per second that may be expected with this device designed to accommodate various flows, and (2) other formulas which may be used in place of the graphical method for design, thus greatly simplifying the procedure. A chart is also given which makes unnecessary the use of the more complicated of the accompanying formulas.

The accompanying figure shows the cross-section of a rectangular grit chamber of depth, D, and width, W, and also the cross-section of the control flume of height, H (somewhat greater than D), and width, W. Mr. Bushee shows in his original article how one may design the control device for a rectangular cross-section and then revise the shape of the bottom of the grit chamber, giving it an equivalent cross-section area. In this article such a revision of the shape will not be considered, but of course it could easily be made.

The figure also shows the maximum departure, *e*, from the velocity of one foot per second which may be expected when the flume is designed to accommodate various ratios, called *r*, of minimum to maximum flows. For example, it appears from this chart that when the minimum flow is one-tenth of the maximum flow, then the maximum departure from velocity of one foot per second will be 10 per cent, or 0.1 foot per second, and when the minimum flow is three-tenths of the maximum flow the maximum departure from the velocity of one foot per second is 3 per cent, or 0.03 feet per second.

The values of *m* and of *f* against *r*, the ratio of maximum to minimum flows, are plotted in the figure herewith. These quantities are ratios which appear in the design formulas. The use of this chart avoids rather cumbersome computations.

Notations in Formulas

In order to present the formulas it is first necessary to explain the notation:

W = Width of rectangular (or equivalent rectangular) grit chamber, in feet.

D = Maximum depth of rectangular (or equivalent rectangular) grit chamber, in feet.

w = Width of Venturi flume, in feet.

H = Maximum depth or head on Venturi flume, in feet.

Q = Maximum rate of flow to be provided for in grit chamber, in cubic feet per second.

r = Ratio of minimum to maximum flow to be provided for in grit chamber, the abscissa of all curves shown on the accompanying chart.

f = Ratio of D to H—a number appearing in formula I and plotted on the graph.

m = An abstract number defined by the second equation below.

e = Maximum departure from a velocity of one foot per second, either in feet per second or as a fraction, plotted in the accompanying figure.

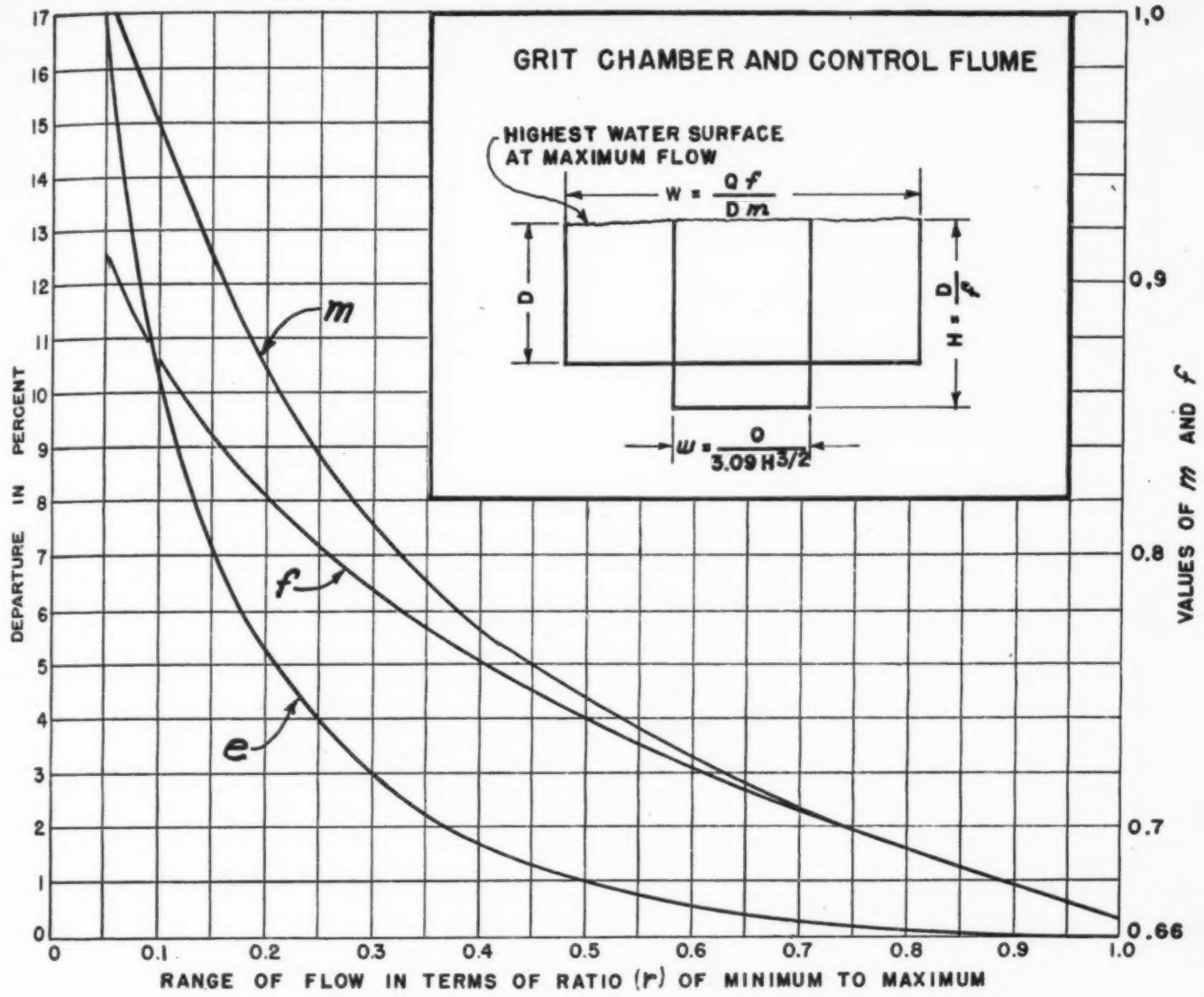


Chart for Aid in Design of Control Flumes for Grit Chambers (For Use with Bushee Method)

The Formulas Involved*

I. $f = \dfrac{(1-r^{2/3})}{(1-r)}$

II. $m = \dfrac{2}{1/f + 2.598\ (1-f)^{1/2}}$

III. $e = \dfrac{m}{f} - 1$

IV. $H = \dfrac{D}{f}$

V. $w = \dfrac{Q}{3.09\ H^{3/2}}$ *

VI. $W = \dfrac{Qf}{Dm} = \dfrac{Q}{Hm}$

The validity of these formulas may easily be tested by application to particular examples.

Illustrative Example:

Assume that Q = 6.2 cu. ft. per sec.
D = 1.8 ft.
r = .3 (i.e., minimum flow is 1.86 cu. ft. per sec.)

Then by I, or from curve, f = .789 and
by IV, H = 2.28 ft.
by V w = .582 ft.
By II, or from curve, m = .811;
by VI, W = 3.34 ft.
By III, or from curve, e = .03 ft./sec. or 3 per cent.

Actual computations show that when Q = 6.2 cu. ft. per sec., or when the minimum flow is 1.86 cu. ft. per sec., v = 1.03 ft./sec. But when the flow is 3.11 cu. ft. per sec., then v is 0.97 ft./sec. This is the minimum velocity attained at any flow between 6.2 and 1.86 cu. ft. per sec. Thus the expected departure (3 per cent) is confirmed.

The formulas given have been based on the following conditions: (1) That the maximum positive departure from a velocity of 1 ft. per sec. which occurs at the maximum flow shall be exactly equal to the maximum positive departure from a volume of 1 ft. per sec. which will occur at the minimum flow, and (2) that this maximum positive departure from a velocity of 1 ft. per sec. shall exactly equal the maximum negative departure from a velocity of 1 ft. per sec. which will occur at an intermediate flow.

WALLACE & TIERNAN CO., INC.

Manufacturers of Chlorine and Chemical Control Equipment

Newark 1, New Jersey

"THE ONLY SAFE SEWAGE IS A STERILIZED SEWAGE"

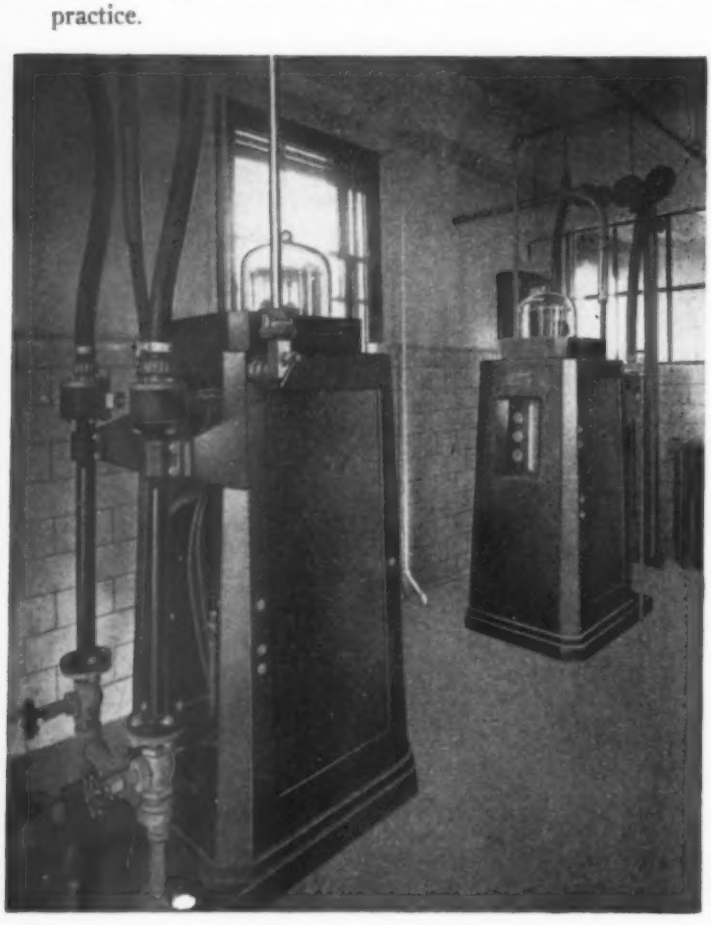
REPRESENTED IN

Albany	Chicago	Greensboro	Knoxville	Minneapolis	Salt Lake City
Atlanta	Cleveland	Houston	Lexington	Oklahoma City	San Francisco
Boston	Columbus	Indianapolis	Los Angeles	Philadelphia	Seattle
Bridgeport	Dallas	Jacksonville	Louisville	Pittsburgh	St. Louis
Buffalo	Denver	Kansas City	Lubbock	Portland, Ore.	Syracuse
Charlotte	Detroit			Roanoke	Washington, D. C.

Wallace & Tiernan Ltd., Toronto, Canada
Wallace & Tiernan Ltd., Winnipeg, Canada
Wallace & Tiernan Ltd., Montreal Canada
Wallace & Tiernan Ltd., London, England

DISINFECTION OF SEWAGE

The need for sewage disinfection cannot today be overlooked. With increasing population the growing demands on water supplies necessitate using sources of supply hitherto considered unsuitable. The increasing popularity of swimming has led to the use of the most available bathing beaches, lakes and water courses. The national resentment against the pollution of streams and rivers is gaining momentum. All of these have centered the attention of sanitarians on sewage treatment. As a final measure of securing complete health protection, sewage disinfection, with chlorine, is accepted practice.



W&T Master Automatic Visible Vacuum Chlorinators. Stamford, Connecticut, Sewage Treatment Plant.

ODOR CONTROL

The control of obnoxious odors from sewage treatment works, long outfall sewers and other disposal plant appurtenances is distinctly a field for chlorination. Neutralization of hydrogen sulfide (the gas responsible for these obnoxious odors), or prevention of its formation by controlled application of chlorine, is not only quite practicable but also results in economy of operation due to reduction of deterioration in interceptors and allied appurtenances.

B.O.D. REDUCTION

Treatment plants discharging effluents into water courses having extreme seasonal variation in flow have profited from controlled chlorination to reduce biochemical oxygen demand. Field tests have often shown a reduction in the five day B.O.D. of up to 30 per cent.

OTHER ADVANTAGES

Similarly, chlorine prevents filter "ponding." It is also widely used to prevent sludge "bulking." Where grease is a problem, chlorine will aid in its removal and minimize its accumulation in small pipes and spray heads. When added to return supernatant liquor from digesters, chlorine tends to counteract the impact of highly putrefactive liquids from fresh sewage. The thickening of sludge may be greatly benefited by the maintenance of a "chlorine blanket" in the supernatant above the sludge. Chlorine is also useful in the preparation of coagulants such as "chlorinated copperas." Difficult trade wastes, such as those containing cyanides, can be effectively purified by designing means for the application of chlorine into the process.

EQUIPMENT

For every sewage plant, there is W&T Equipment to fit. Visible Vacuum Chlorinators with capacities from ounces to 6000 pounds per day—Solution Feed and Direct Feed Chlorinators for small plants—and Reagent and Chemical Feeders to meet many varied chemical treating applications. All W&T Apparatus is backed by over thirty years' experience and is job-engineered by chlorination specialists.

TECHNICAL INFORMATION

W&T representatives will gladly discuss any specific sewage chlorination problem. Technical bulletins on the many phases of sewage chlorination and W&T Chlorinators will be sent free on request.

CONTROL OF ODOROUS AND DESTRUCTIVE GASES IN SEWERS AND TREATMENT PLANTS

By CHAS. C. HOMMON
Supervisor of Sewage Treatment
Canton, Ohio

THERE are heterogeneous odors from sewers and sewage treatment plants. The so-called sewer gas often referred to in nontechnical language by the layman is not a specific gas. It is an all inclusive term meaning any gas or combination of gases that may be found in a sewer. The most objectionable and far-traveling odorous gases are those originating from stale and septic sewage. Of these volatile compounds, which are expelled from septic sewages, hydrogen sulphide is by far the greatest offender.

This gas, besides creating odor nuisance of intensity and travel distance in proportion to its concentration, has a second and decided objection. It is a dangerously toxic gas in dilution higher than most operators and engineers realize. By authorities it is rated with hydrocyanic acid gas in respect to its toxicity. It is treacherous because individuals working in fatal concentrations lose their sense of smell. Operators working in less than fatal concentration become accustomed to the odor but in time suffer permanent injuries—notably conjunctivitis and respiratory tract inflammation.

Destructive Effects of Sulphide Gas

In addition to the toxicity, hydrogen sulphide is responsible for costly damages to sewers and plant equipment. Copper parts on expensive switchboards and control panels are in short order sulphided and flaked away or crumble to black copper sulphide powder. Short work is made of copper screens and brass work exposed to the moist gas at sewage plants. The first sign is the iridescent blue coloring imparted to copper and its alloys. Hydrogen sulphide can also be easily and simply detected by exposing silver coins for a few hours at points where presence of the sulphide gas may be suspected. The coins turn brown and then black if sulphide gas is present.

Then, one of the most disastrously damaging effects from hydrogen sulphide is its hidden attack. This is the acid disintegration of masonry sewers and all metal parts of manhole structures. The sulphide gas in this type of attack is converted by organisms (bacteria) on the walls of sewers into two acids, sulphurous and sulphuric. It hardly needs be explained that both of these acids make short work of concrete or mortar. The calcium sulphate produced causes rupture of mortar pipe joints and brick sewers or manholes. It has been known to weaken sewers to the point of complete failure of that part above the sewage flow line, below which no damage is done. Therefore, no full flowing sewer is ever damaged by sulphide gas. This gas is never oxidized by organisms which are present in the liquid but only those which thrive in an atmosphere where there exists some oxygen. If, therefore, it were practical to seal sewers so as to prevent all entry of air, there would be no danger of the so-called gas attack of sewers and manholes.

An Instance

The sanitary outfall sewer extending from the southerly city limits of Canton, Ohio, to the treatment plant offers good evidence as to the destructiveness of sulphide gas.

This sewer is 39 inches in diameter, 6.5 miles in length, and was placed in service in 1915. Type of construction was vitrified segment block laid up with mortar joints, and has a theoretical carrying capacity of 18 m.g.d. There is one depressed section, 3,200 feet in length, which is constructed of reinforced concrete. This length of sewer is naturally conducive to septic sewage and consequent development of hydrogen-sulphide, especially during the warmer months of the year. The presence of offensive gases was not particularly grievous with the Imhoff contact bed type of sewage plant that was the original companion unit of this outfall sewer. However, in 1925, when the original contact bed units were converted into trickling filters using the conventional spray nozzles that were in general use at the time, the volatile gases made their presence known through the atomizing effect of the spray nozzles. Thus originated a definite odor problem.

An Early Study in Corrective Treatment

In about 1928 through the efforts and assistance of Mr. L. H. Enslow, associated with The Chlorine Institute, some work was undertaken using liquid to control the odors. The Institute furnished the chlorine and the firm of Wallace and Tiernan loaned the necessary chlorine feeding apparatus for the study.

Chlorine was first added to the sewage at a point locally known as the three way manhole, which is the beginning of the main outfall sewer. This station is 6.5 miles above the Treatment Plant and is the point of convergence of three main trunk sewers.

A number of sampling points were established along the sewer for collecting samples for analysis. It was soon learned that the chlorine would do the trick of controlling the hydrogen-sulphide. However, it was difficult to maintain sufficient chlorine and the required dosage was relatively high. The receding area in the depressed section caused an appreciable increase of hydrogen sulphide which, it was believed, defeated the desired results at the plant. It was obvious that split feeding was the answer; just how many points of desired application were not determined because of the absence of necessary water pressure for operating the chlorine machines at locations below the three-way manhole.

The chlorinators were then moved to the sewage plant and chlorine admitted to the raw sewage just ahead of the bar screens.

This work clearly indicated that a dosage of 10 to 12 p.p.m. would greatly improve conditions at the plant and eventually permanent chlorination equipment was purchased and storage

One of the Early Up-Sewer Chlorinating Stations for Odor Control and Sewer Protection—San Bernardino, Calif. This picture reveals the small space required for such a station and the method of transfer of the one-ton chlorine cylinder from truck to the in-use pit alongside the chlorinator house. Incidentally this picture was taken just after California's worst floods and half-buried the chlorinator house in deposited silt. With the treatment plant put completely out of commission, this station performed an emergency service of disinfection of the bypassed sewage during the restoratiion by merely boosting the chlorine dosage.

See also article by R. F. Brown, page 181, *W. W. & S.*, May, 1947—*"Up-Sewer Chloroben Treatment of Los Angeles Sewage,"* as a means of inhibiting the progressive production of malodorous and destructive hydrogen sulphide.

racks for handling ton containers of chlorine were constructed. At this time odor control was the all absorbing question, with only minor consideration given to the need for deterring disintegration of the mortar tile joints and concrete structures.

Attack on these, however, became accelerated in the time intervening and the expensive Canton outfall sewer, weakened by joint attack, has ruptured three times in the past few years. Internal pressures, caused from surcharging, proved too much for the weakened joints. These failures offered good reasons and opportunities for a thorough inspection of the sewer and it was found that practically all of the mortar joints above the normal flow line had disintegrated and ceased to exist. Also many of the liner plates were split off and were found lying on the floor of the sewer. It is assumed that the swelling of the mortar in the joints during the sulphating period created sufficient pressure to pinch off the faces of these tile. In a few instances the velocity of the sewage had caused these fallen plates to gather into sufficient piles to develop major restrictions in the sewer. It was interesting to note that the portion of the sewer below the normal flow line was in a very satisfactory condition, no plates missing and all joints normal, whereas the upper areas showed serious attacks. This same condition prevailed in the approaches to the concrete depressed section. Wherever the concrete mortar was submerged it was in a satisfactory condition, but above the normal flow line (those areas normally in contact with moisture and the gases) serious deterioration was evident.

The Original Contact Towers for the Scott-Darcey Process of Making Ferrous and Ferric Chloride at Oklahoma City.

Discharge from chlorinators passes upwards through iron scrap, producing ferrous chloride.

A great deal more is known today about sewage treatment and the handling of sewage than was available when the Canton outfall sewer was constructed and the writer is frank in admitting that he did not fully appreciate what had occurred or what was occurring in the sewer at the time this investigational work was being done. As a matter of fact, there was little if any evidence in 1928 to show that the attack was proceeding at a serious pace, and chlorination at the plant proper seemed adequate for the odor problem.

Methods of Preventing Sulphide Production

Hydrogen sulphide develops only after all other sources of available oxygen utilizable by bacteria have been exhausted. After this, the oxygen hunger of several species of bacteria is satisfied from the only source left—the sulphates. In taking away the oxygen, the residue is sulphide, which hydrolizes into hydrogen sulphide.

Having laid down this premise, it becomes apparent that there are two general methods of preventing or checking sulphate breakdown. These are:

(1) Introducing more oxygen in the form of air, dilution water containing oxygen, or an oxygen containing compound such as nitrate.

(2) Suppression of bacterial activity and multiplication of organisms which deplete the oxygen and eventually break down the sulphates for their oxygen content.

The sewage operator may employ the following corrective methods:

(1) Air blowing to sweep out most of the volatile (free) hydrogen sulphide and discharge of the air-sulphide exhaust through a tall stack. Or absorption of the sulphide in the exhaust may be attained by passing it through an absorption tower.

(2) Destruction of the sulphide in the sewage by addition of chlorine, which precipitates the sulphur *in situ* and deodorizes in so doing.

(3) The fixation of the sulphide by adding a metallic salt such as copper or iron.

These several methods will now be discussed separately.

(1) Oxygen Introduction

Air blowing in the sewer sounds attractive but has many drawbacks of a practical nature. The scheme has never been successfully developed because of structural and operating expense. The effect secured with flash aeration has short duration, as all activated-sludge plant operators will attest. As a matter of fact, a small air input is worse than none in the overall result, since bacterial multiplication is given impetus and oxygen supply is too limited.

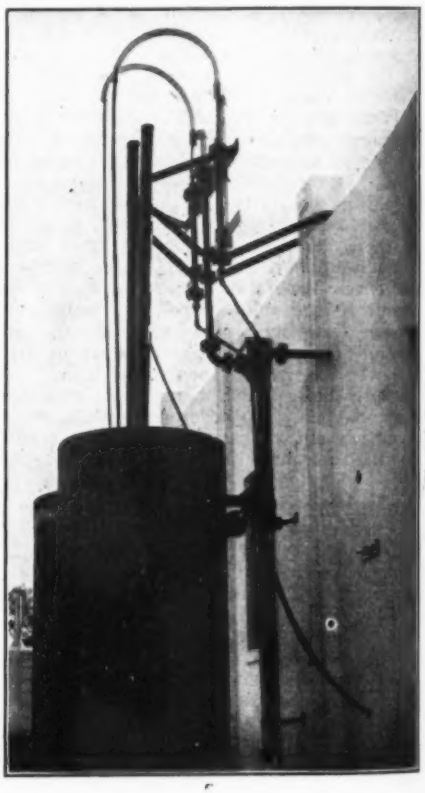
The addition of nitrates (Chilean Saltpeter) has been used; is effective but surprisingly costly in terms of oxygen units provided.

Dilution, by introducing reasonably clean stream water upsewer, has been utilized with excellent results during hot dry-weather flow when the practice is most needed, and fortunately is permissible at such times without surcharging sewers or imposing excessive flows on treatment works. Fortunate is the plant manager who can divert a portion of a stream into his sewer system when most needed to maintain clean sewers, dilute and freshen sewage delivered to the plant at much younger age, and prevent degradation and odor production in the system.

(2) Suppression of Bacterial Activity

In winter, lower temperatures of sewage is the natural suppressor of bio-activity. If it were practical to chill sewage to maintain temperatures of not in excess of 70° F. during its travel through the system there would be no odor or sewer attack problem.

The practical alternative is that of partial disinfection of sewage to reduce the total numbers of organisms, suppress their development, and most important of all, to reduce the biological "turnover." What is meant by "turnover" is the number of new generations of young and vigorous organisms per hour. Like all living things, it is the active youth generation who burn up the oxygen in the vigor of living, and not the grandfather generation. Total numbers of organisms may mean little if anything in sewage. What really counts is the age, activity and species of bacteria. This means much in rate of oxygen utilization and depletion, consequently, the speed of reaching the point of sulphide production and its consequences.



Contact Towers for the Scott-Darcey Process at a Small Treatment Plant in Arizona.

In this instance the chlorinated iron produced is employed for chemical precipitation as well as odor control.

To suppress bacterial "turnover" and rates of oxygen deple-

tion, such as is provided by nature in winter operation, is the basis on which partial disinfection of sewage as close to its point of origin as practical, has met with success. Some remarkable results have thus been obtained with up-sewer chlorination at rates of dosage dictated by the temperature-time factor. In some instances (cooler sewage and short period of travel to the plant) as little as 2 p.p.m. of chlorine has been ample. In other instances (drought and high temperatures with long travel periods to the plant) as much as 12 p.p.m. has been required. In others, a two-point application, between the collecting system and the plant, has been required for higher efficiency and chlorine economy. Taking it by and large, the 5 p.p.m. dosage has been effective when applied sufficiently early—i.e., before bacterial "turnover" has gotten a head-start.

During the past several years "preventative chlorination" has been the most popular odor control measure. No set rule can be given for the dosage needed, for reasons above cited. Nor can a universal specification be written concerning the point (or points) of chlorine introduction up-sewer. Therefore, in cases where doubt exists, a hydrogen sulphide and chlorine-demand survey to determine the most effective application point (or points) is the recommended procedure. As a matter of fact, a portable chlorinator may be employed to determine the permanent location (or locations) for maximum chlorine economy.

In connection with such surveys and chlorination point selection, securing assistance of experienced engineers with The Chlorine Institute, 50 E. 41st St., New York City, or the technical service staff of Wallace & Tiernan Co., and/or of the larger chlorine producers, is suggested.

Other Corrective Methods

In cases where it has not proved practicable to adopt preventative measures, the following corrective methods are available.

(1) Air Blowing at Plant

So far as we are aware, this method has only been utilized at one plant—Dallas, Texas. In a closed chamber the sewage arriving at the treatment works is air-blown for 4 minutes and in the second pass is blown for an additional 4 minutes with air carrying chlorine gas. The exhaust from the aerating and aero-chlorination chamber is discharged through a stack. The plant is also equipped to employ ordinary chlorination or the addition of an iron salt, which will destroy or "fix" the volatile sulphides, as later explained.

(2) Chlorination

By far the greatest number of plants have been equipped for corrective chlorination at the plant proper, when and if odors become a problem. Particularly has this method been mostly adopted for the smaller plants and those where odor nuisance is a possibility rathter than a probability.

In this method, chlorine is applied just ahead of the bar-screens or in the pump well. The dosage varies considerably, running from 2 to 20 p.p.m. of chlorine. In the majority of such cases, the 10 p.p.m. dosage covers the requirement. The practice of pre-chlorination for the dual purpose of disinfection and odor control simultaneously has gained considerable favor in recent times, the largest plants to adopt this method being those of Buffalo, N. Y., and Detroit, Mich., where pre-chlorination has also proved more economical than post-chlorination, and also more effective as a disinfection measure alone.

In the plant chlorination method the sulphide is destroyed by breaking into the compound and precipitating the sulphur thus

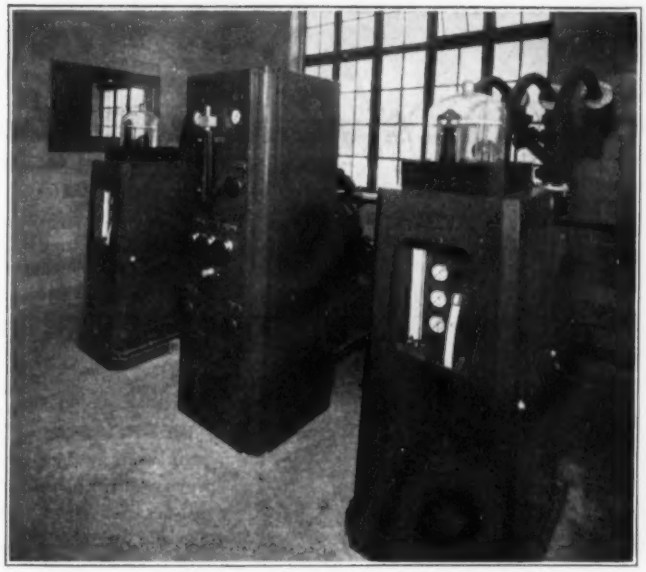
$$H_2S + Cl_2 = 2HCl + S$$

(3) Sulphide Fixation

When adding chlorine *solely* for the purpose of sulphide destruction (i.e., after the sulphide has been produced), the scheme is less effective than the following.

Copper or iron salts may be employed for the purpose of converting volatile sulphide into "fixed" copper or iron sulphide. Since copper is the more costly metal, and since iron chloride can be produced relatively simply and inexpensively on the site of application, this scheme has in recent times become a very popular, effective and inexpensive method.

The iron chloride is produced from scrap iron and chlorine by passing the discharge of a chlorinator upwards through a tank or tower containing the iron scrap. The overflow from the tower is ferrous chloride ($FeCl_2$). The process introduced in Oklahoma City by L. H. Scott, Supt. of Water and Sewage Treatment, and H. J. Darcey, Chief Engr., Oklahoma State Dept. of Health, and known as the Scott-Darcey Process, was taken over and perfected by Wallace & Tiernan Co. In the West and Southwest the method has been rather extensively and effectively used. With the equipment, either iron chlorine or chlorine may be used at will. The equipment can also be operated to produce ferric chloride ($FeCl_3$) for coagulation or sludge filtration at will.



The Triple Purpose Chlorinator Installation at Dallas, Texas The 1,000-lb. capacity dry feed machine at center is used for "Aero-Chlorination" in grease separation and/or deodorization of stack gas. The two 2,000-lb. capacity solution machines are used for prechlorination odor control or producing chlorinated copperas at will.

In the matter of odor correction, the use of chlorinated iron has many advantages over direct chlorination. For instance, there are stale sewages which when chlorinated partially develop decidedly medicated (iodoformish) odors. This odor is not of a traveling nature but is not pleasant and visitors would object to it. On the other hand, chlorinated iron produces absolutely no odor. For a given amount of chlorine, use of the Scott-Darcey method insures 100 per cent efficiency in respect to theoretical hydrogen sulphide removal per pound of chlorine. The explanation lies in the fact that the iron has affinity only for the sulphide and fixes it completely without organic matter interference, while chlorine is always in part used up by organic matter before it strikes the sulphide. Frequently 50% of the chlorine applied is thus used up and only 50% ever reaches the sulphide.

A fact of considerable interest also is that the iron application can be made at any point desired. If, for instance, it is desirable to add it at the beginning of a long sewer, the iron is used up only as hydrogen sulphide is produced. Therefore, the surplus of iron travels along in contact with the sewage or industrial waste without being depreciated in any degree by the organic content. Thus, the iron becomes available as needed during progress of the sewage between the point of application and the plant. It is plain, therefore, that the chlorinated iron method is a measure of correction which involves the utilization of chlorine to its highest advantage. The method insures an efficiency of hydrogen sulphide removal at essentially 100 per cent of the theoretical, this being the destruction of 1 p.p.m. of H_2S for each 2 p.p.m. of chlorine applied, according to the reaction:

$$H_2S + Cl_2 = 2HCl + S$$

The reactions involved in the chlorinated iron method are:

(1) $Fe + Cl_2 = FeCl_2$

(2) $H_2S + FeCl_2 = 2HCl + FeS$

Since two parts of chlorine by weight accounts for one sulphur, the iron involved can be pictured as a chlorine carrier in the process of "indirect chlorination."

From the above, it is readily observed that the more modern use of chlorine as an agent of controlling hydrogen sulphide would have been of material benefit in preventing failure of Canton's 26 year old outfall sewer, as well as correcting the odor problem at the plant proper. When considering the cost of a large outfall of material length it is apparent that considerable can be spent for Summer time chlorination as a measure for extending the life of such a structure

Check Your

Water, Sewage and Industrial Waste

• As specialists in the design and manufacture of equipment for Water, Sewage and Industrial Waste Treatment Plants, Link-Belt engineers have learned how to apply an extensive knowledge and experience effectively, to the solution of such problems.

For many years, Link-Belt engineers have cooperated with consulting, municipal and sanitary engineers, and plant operators in planning and operating plants, for positive results and highest efficiency. It will pay you to check your plans and specifications with Link-Belt engineers.

STRAIGHTLINE COLLECTORS

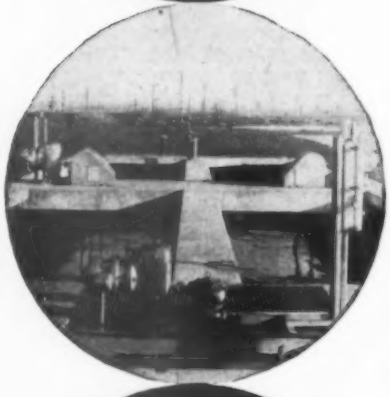
Link-Belt STRAIGHTLINE Sludge Collectors for the removal of sludge from rectangular settling tanks consist of two strands of especially processed malleable chain from which are suspended at uniform intervals scraper flights usually made from red wood. Features are peak-cap bearings, pivoted flights, cross collectors for larger tanks, and positive sludge removal at a slow, uniform speed. Automatic or semi-automatic skimming equipment is furnished when required.

Many installations are now in service in all parts of the country and range in size from the smaller type plants as at Tappahannock, Va., with a capacity of 80,000 G.P.D., to larger installations, such as Ward's Island, N. Y., with a capacity of 180,000,000 G.P.D., and Southwest Plant, Sanitary District of Chicago with a maximum capacity of 600,000,000 G.P.D.

Many features of the Link-Belt STRAIGHTLINE Collector are patented. Send for Book No. 1742.

CIRCULINE COLLECTORS

Link-Belt CIRCULINE Collectors for the removal of sludge from round tanks consist of a flight conveyor suspended from a bridge, one end of which is pivoted at the center and the other end is mounted on standard rubber-tired wheels which travel around at circumference of the tank. Features are: positive, slow, uniform speed; positive sludge removal and excellent distribution of flow throughout the tank; improved automatic scum collecting screw conveyor and scum receiving hopper as standard equipment. Made in two standard sizes — Type "B" for Tanks up to 55′ dia.; Type "A" for larger sizes up to 200′ dia. Send for Book No. 1982.



STRAIGHTLINE MIXERS

Link-Belt STRAIGHTLINE Mixers of the vertical or horizontal type have proved their value in reducing chemical costs and promoting efficient flocculation in water and sewage treatment plants. They consist of a shaft to which is fastened arms which carry either wood or steel paddles that can be pivoted so that the flights can be adjusted to obtain the exact degree of uniform agitation. The maximum circumferential speed of the mixers for flocculation tanks is 1.8 f.p.s., and the minimum speed is about half of that. A gradual decrease in speed of the units is desirable for efficient flocculation.

Send for Book No. 2042.

BIO-FILTRATION System for Treating Sewage

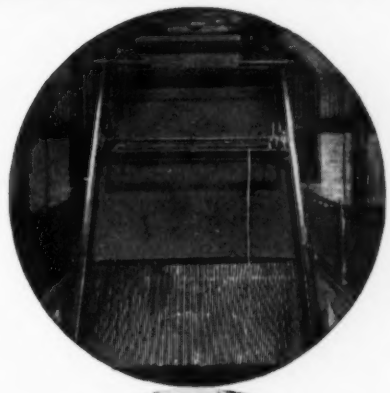
Bio-Filtration Sewage Treatment System with Link-Belt STRAIGHTLINE and CIRCULINE Collectors brings new advantages. The system consists of high rate shallow filter beds and recirculation of the effluent from the filter beds to the primary tanks. Features are great flexibility, high rate of B.O.D. loading and the ability of such a plant to handle strong domestic and industrial sewage in single-stage or two-stage treatment, as required. A large number of installations of this type are now in operation. Send for Folder No. 1881.

Treatment Plans with LINK-BELT

STRAIGHTLINE BAR SCREENS

Link-Belt STRAIGHTLINE Mechanically Cleaned Bar Screens have spaced parallel bars on which the larger floating solids in incoming sewage collect, and a mechanically operated rake for removal of the accumulating solids, thus assuring an even flow of sewage through the channel. The machine may be set vertically or inclined, and used in small or large plants.

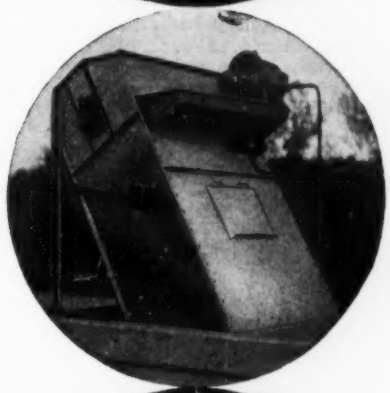
Send for Booklet No. 1587.



TRITOR SCREENS

The Link-Belt Tritor Screen is a combination mechanically cleaned screen and grit chamber. It is especially designed for medium and small size plants. Its main elements are a hopper, a bar screen, and a bucket elevator for removing the solids accumulated on the screen and the grit from hopper. The buckets are perforated for drainage and have rake teeth for cleaning the screen. Adjustable baffles regulate velocity of flow through the hopper.

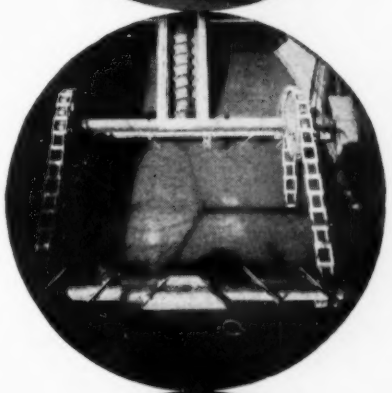
Send for Booklet No. 1587.



STRAIGHTLINE GRIT COLLECTORS and WASHERS

The Link-Belt STRAIGHTLINE Grit Collector and Washer collects the settled grit and frees it from putrescible organic matter. This unit consists of a scraper type collector with pitched flights, and an inclined washing and dewatering screw to which the collector conveys the grit. The grit is discharged washed and dewatered above the water level by the screw.

Send for Book No. 1942.



INDUSTRIAL WASTE SCREENS

The Link-Belt Industrial Waste Screen is an efficient and economical unit for the removal of objectionable suspended solids from industrial waste before the water is discharged into sewers or streams. The screenings come off the machine with a minimum of moisture. Units are available in several sizes and with coarse or fine screen medium. Wastes from canneries, textile mills, steel mills, etc., are handled successfully by these screens. Send for Book No. 1977-A. We also manufacture rotary screens for similar service.

OTHER LINK-BELT EQUIPMENT INCLUDES: STRAIGHTLINE Scum Breakers for Digestion Tanks; Air Diffuser Units for degreasing, aeration and mixing of liquids; Non-Clogging Spray Nozzles; Traveling Water Intake Screens; Rotary Screens; Roto-Louvre Heat Dryers; Coal and Ashes Handling Machinery; Car Spotters and Haulage Systems; Shovels-Cranes-Draglines—Crawler and Wheel Mounted; and a complete line of Elevating, Conveying and Power Transmission Machinery. Catalogs sent on Request.

LINK-BELT COMPANY

10,288-B

•Atlanta.....1116 Murphy Ave., S.W.
Baltimore 1.....612 Keyser Bldg.
Birmingham 3.....Comer Bldg.
•Boston 15.....136 Brookline Ave.
Buffalo 3.....688 Ellicott Square Bldg.
•Chicago 9.....300 W. Pershing Rd.
Chicago 8.....2410 W. 18th St.
Cincinnati 2.....730 Temple Bar Bldg.
Cleveland 13.....548 Rockefeller Bldg.
•Dallas 1.....500 Latimer St.
Denver 2.....521 Boston Bldg.
•Detroit 4.....5938 Lindsale Ave.
Grand Rapids 6....1012 Cherry St., S.E.
Houston 2.....711 Main St.
Huntington 9, W. Va.....1301-2 West Virginia Bldg.
Indianapolis 6.....220 S. Belmont Ave.
Indianapolis 6.....519 N. Holmes Ave.
Kansas City 6, Mo...1004 Baltimore Ave.
•Los Angeles 33..361-369 S. Anderson St.
Louisville 2.....1195 Starks Bldg.
Milwaukee 3.....808 N. Third St.
•Minneapolis 5.....200 Lyndale Ave., N.
Moline, Ill.....1608 Fifth Ave.
Newark 2, N. J.....9 Clinton St.
•New Orleans 13...747 Tchoupitoulas St.
New York City 7.....233 Broadway
•Oakland 7, Calif.....1025 Harrison St.
•Philadelphia 40.2045 W. Hunting Pk. Ave.
Pittsburgh 19.....436 Seventh Ave.
•Portland 9, Ore....1637 N.W. 14th Ave.
•San Francisco 24.....400 Paul Ave.
St. Louis 1.....317 N. 11th Ave.
Schenectady 5.....243 State St.
•Seattle 4.....3405 Sixth Avenue, S.
•Spokane 8.....South 151 Lincoln St.
Wilkes-Barre..726 Second Nat'l Bk. Bldg.

In Canada—Link-Belt Limited—•Toronto 8, Eastern Ave. at Leslie & Keating; •Montreal 18, 180 Vallee St.; •Vancouver, 550 Beatty St.; •Swastika, Ont., 8 Boisvert St.
Shovel-Crane-Dragline Division—Link-Belt Speeder Corp., 301 W. Pershing Road, Chicago 9; 1201 Sixth St., S.W., Cedar Rapids
•Also Factory Branch Stores
Distributors Located in Principal Cities and Representatives Throughout the World.

BAILEY METER COMPANY

1072 Ivanhoe Road, CLEVELAND, OHIO

BOSTON NEW YORK PHILADELPHIA BUFFALO PITTSBURGH CINCINNATI ATLANTA DETROIT CHICAGO
MILWAUKEE ST. LOUIS ST. PAUL KANSAS CITY HOUSTON DENVER LOS ANGELES SEATTLE SAN FRANCISCO

BAILEY METER COMPANY LIMITED, Montreal, Canada

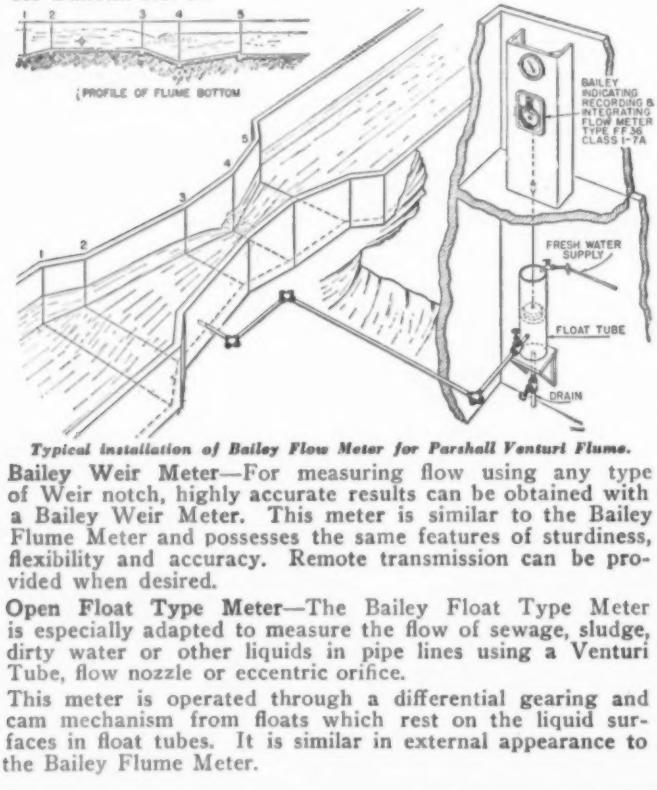
METERS, GAGES and CONTROLLERS for SEWAGE TREATMENT and WATER SUPPLY

STANDARD BAILEY REGISTERS

Bailey Flume Meter—Simplicity of installation, low head losses and self-cleaning features of the Parshall Flume have resulted in a greatly increased use of this device for a measurement of Sewage Flow in open channels.

The Bailey Flume Meter is simple and accurate. As shown in the illustration, it consists of a single float which is connected by a flexible cable to the sturdy recording, integrating and indicating mechanism on the panel board. The panel board may be omitted if desired and the recording mechanism mounted on a wall or column. This device may be adapted to any type of open channel metering over any operating range required. Its capacity can be altered in the field by installing new gears and/or cam without disturbing any other parts of the installation.

Standard Bailey Indicating, Recording and Integrating Instruments are used, charts are 12 inches in diameter and uniformly graduated. Instruments may be placed in remote locations by the addition of Bailey Telemetering Systems. Ask for Bulletin No. 62.


PROFILE OF FLUME BOTTOM
BAILEY INDICATING RECORDING & INTEGRATING FLOW METER TYPE FF 36 CLASS I-7A
FRESH WATER SUPPLY
FLOAT TUBE
DRAIN

Typical installation of Bailey Flow Meter for Parshall Venturi Flume.

Bailey Weir Meter—For measuring flow using any type of Weir notch, highly accurate results can be obtained with a Bailey Weir Meter. This meter is similar to the Bailey Flume Meter and possesses the same features of sturdiness, flexibility and accuracy. Remote transmission can be provided when desired.

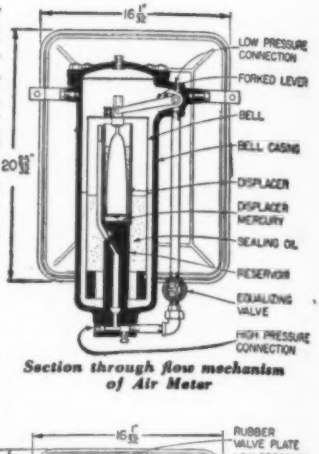
Open Float Type Meter—The Bailey Float Type Meter is especially adapted to measure the flow of sewage, sludge, dirty water or other liquids in pipe lines using a Venturi Tube, flow nozzle or eccentric orifice.

This meter is operated through a differential gearing and cam mechanism from floats which rest on the liquid surfaces in float tubes. It is similar in external appearance to the Bailey Flume Meter.

Bailey Fluid Meter—The flow of steam, liquids and gases in pipe lines at high or low pressures can be accurately measured by the Bailey Fluid Meter. A Venturi Tube, flow nozzle, or orifice is used as the differential producing device and the meter indicates, records and integrates on the standard Bailey Register previously described. Remote recorders may be provided by Bailey Telemetering Systems which operate electrically on alternating current.

In addition to the rate of flow, this meter may also record pressure, temperature or liquid level on the same chart.

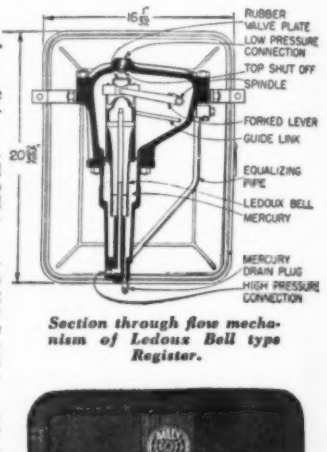
Described in bulletin No. 301-A.



Section through flow mechanism of Air Meter

Air Meters—These meters measure Air Flow in main lines and in individual lines to aeration tanks.

The register is similar in appearance to the Ledoux bell type, and the flow mechanism is designed to operate on a maximum differential pressure of 88-in. of water. *Described in bulletin No.* 301A.



Section through flow mechanism of Ledoux Bell type Register.

Remote Registers — Bailey Telemetering Systems make it possible to operate remote indicating, recording or integrating registers, which may be installed at a distance from the direct connected unit. These registers may measure flow in individual lines, total flow, liquid level, pressure and other factors.

Venturi Tubes—Standard Bailey Designs include a complete range of Venturi Tubes and other prmiary elements suited to the measurement of sewage, sludge and water. The selection of a suitable primary element is governed by such factors as capacity required, type of flanges, pressure loss allowable and character of fluid to be metered.

Controllers—Bailey Controllers utilize standard Bailey Meters and Recorders as the basic measurement source for the automatic control of factors, such as flow, ratio, pressure and liquid level. They are operated by compressed air at approximately 35 lbs. pressure and match perfectly with other Bailey Gages and Registers.

Bailey control is fully automatic, dependable and exceptionally flexible.

Bailey Recorder—Controller.

Bailey Registers measuring Sewage, Sludge and Air in an operating gallery at Easterly Sewage Treatment Works, Cleveland, Ohio.

OPERATION OF ACTIVATED SLUDGE PLANTS

By Gail P. Edwards, Ph.D.
Chief of Laboratories, Dept. of Public Works, City of New York

THE activated sludge process is widely used where a high degree of purification is required. It may be operated with complete freedom from odors and flies, on a minimum area of land. Pearse reported that at the end of 1942, there were 386 plants in the United States.

Theory

In nature, the decomposition of organic wastes is accomplished by the activities of bacteria and other micro-organisms which use complex organic materials as food and break them down into simple, more stable forms. The organic substances contained in sewage form a bountiful food supply for the micro-organisms. When sewage flows over or comes in contact with a suitable surface, growths of bacteria and micro-organisms appear and soon cover the surface with a slimy gelatinous film. This film, which is full of life, has the extraordinary power of first attracting to itself substances that previously had been held in suspension, colloidal state, or even in solution; then of removing from these attracted substances, the food necessary for film maintenance and growth; and finally of returning to the sewage, the end products of decomposition.

The activated sludge process is a method of sewage purification consisting of the aeration of sewage in the presence of biologically active sludge which has previously been produced by the process. It is a true biological contact process. The solids suspended in the sewage form the initial nucleus or contact surface to which the slime forming biological growths adhere. Large flocs of suspended matter are formed by bacterial growth. By voracious feeding, the organisms in the floc cleanse or restore the active contact surfaces; hence they are called "activated" sludge flocs. This floc contains living, growing organisms which require oxygen for life.

Activated sludge, as defined by Donaldson, is a brownish gelatinous material consisting mainly of micro-organisms produced during the continued aeration of sewage. A flow diagram of a simple activated sludge plant is shown in the accompanying diagram.

In practice, the sewage mixed with returned activated sludge flows through aeration tanks where air is added. From the aeration tanks, the effluent discharges into final settling tanks where the activated sludge settles out. Most of the sludge is returned to the aeration tanks to inocculate the sewage. The effluent from the final settling tanks is clear, free from color and odorless.

Aeration may be accomplished in several ways:

1. Diffused air aeration: Air is blown into the sewage as it flows through the tanks.
2. Mechanical aeration: Mechanical apparatus is employed to aerate the sewage and keep the solids in suspension. Absorption of air takes place at the surface of the liquid.
3. Combined use of diffused air and mechanical aeration: A reduced amount of air is blown into the sewage while mechanical apparatus keeps the liquid in circulation.

The material in this paper applies particularly to diffused air plants.

Starting Units in Operation

Before placing units in operation, tanks and pipe lines must be free of debris and all mechanical equipment in working order.

The most common method of starting an activated sludge plant in operation is by the continuous flow method. The sewage is allowed to flow through the tanks continuously and all sludge from the final tanks is returned to the aerators. Some purification will be obtained in a few days, but from one to three weeks are generally necessary to produce normal purification. When the concentration of suspended solids in the aeration tank has reached a satisfactory value, excess sludge should be withdrawn from the system at a rate which will keep the concentration of solids in the aeration tanks fairly constant.

Variables in Operation

The most important variables under the control of the operator of an activated sludge plant are:

1. Volume of air applied.
2. Concentration of suspended solids in aeration tank.
3. Aeration period.
4. Rate of sludge return.
5. Condition of the sludge.

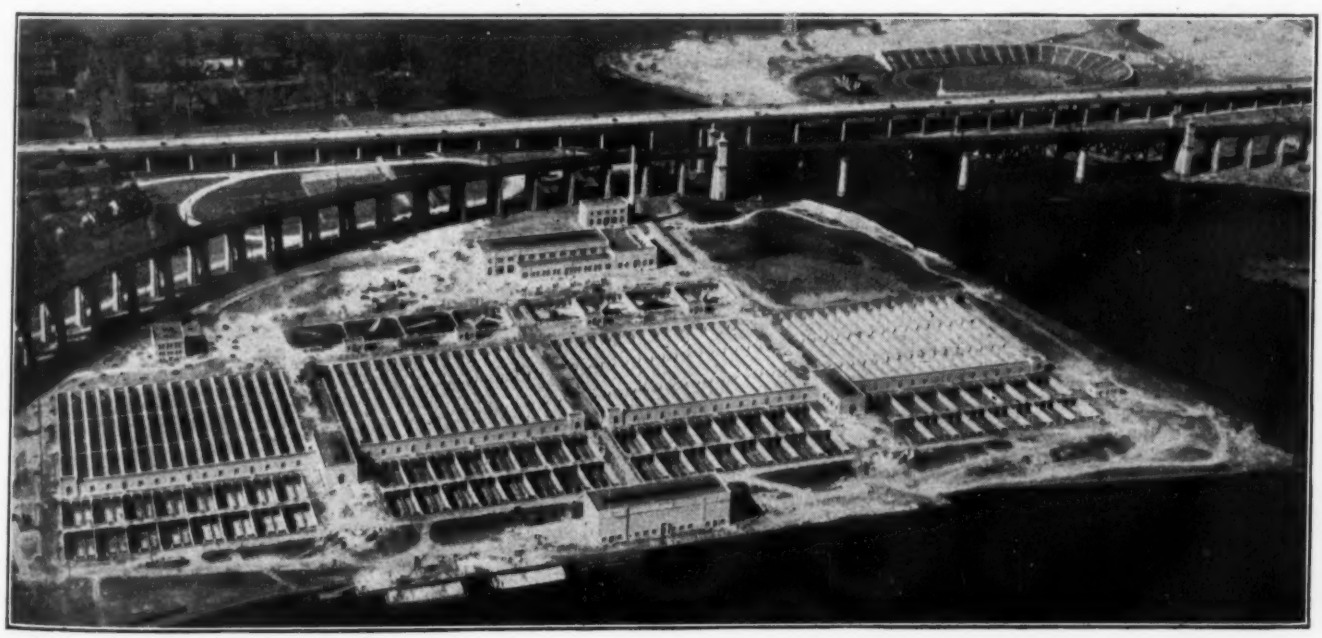
Operating data from several activated sludge plants are shown in Table I.

These variable factors must be properly controlled according to local conditions and changed as necessary to meet seasonal variations and fluctuations in load. They depend upon each other and a change in one will generally require changes in some of the others.

Volume of Air Applied: The volume of air applied is important not only as far as treatment is concerned but also because it determines the cost for power. In diffused air plants, the air is used to keep the solids in suspension, to obtain thorough mixing, and to supply oxygen for the microscopic organisms. It is essential to maintain aerobic conditions throughout the system (aeration and final settling tanks) for best operation. It is wasteful to use more air than necessary and injurious to treatment to use less than the required amount.

The average amount of air used varies from about 0.30 to 2.0 cu. ft. per gallon of sewage. These values depend on the concentration of aeration solids, the aeration period, and the strength of sewage.

The quantity of air used is sometimes expressed in cu. ft. per pound of BOD. removed. This method of expression has the advantage of showing the work done or



Wards Island Sewage Treatment Plant, New York City (Diffused Aeration)

the efficiency of the use of the air. As shown in Table I, values may range from about 350 to about 2200 cu. ft. of air per pound of 5 day BOD. removed. In comparing data from various plants, it is important to note that economy in use of air may not be important at plants where air compressors are operated by sludge gas engines.

The amount of air used is generally controlled by determinations of dissolved oxygen from one or more points in the aeration or final tanks. Some operators determine the dissolved oxygen content at the inlet and midpoint as well as at the outlet end of the aeration tanks. Others control the air from samples taken in the final tanks. Generally the dissolved oxygen is lowest near the influent end of an aeration tank and it increases gradually to the effluent end. A dissolved oxygen content of 2.0 — 5.0 ppm. is generally required at the outlet end of the areation tanks in order to maintain aerobic conditions throughout the tanks.

In the activated sludge process, the entire load of sewage is normally added to the return sludge in a single dose at the inlet end of the aeration tanks. Consequently, the demand for oxygen is very high there. This demand for oxygen decreases as the sewage passes through the tank, reaching a minimum at the outlet end. In order to meet this high initial demand for oxygen, it has been proposed to add the largest amount of air at the inlet end and gradually decrease it toward the outlet. This method, called "tapered aeration," is being used at a number of plants.

Gould has suggested that instead of tapering the air, adding the sewage to the returned sludge in steps would even out the demand for oxygen throughout the aeration tanks. In New York City, he has provided for the addition of sewage to the returned sludge at three points in the aeration tanks. This process is called "step aeration."

TABLE I

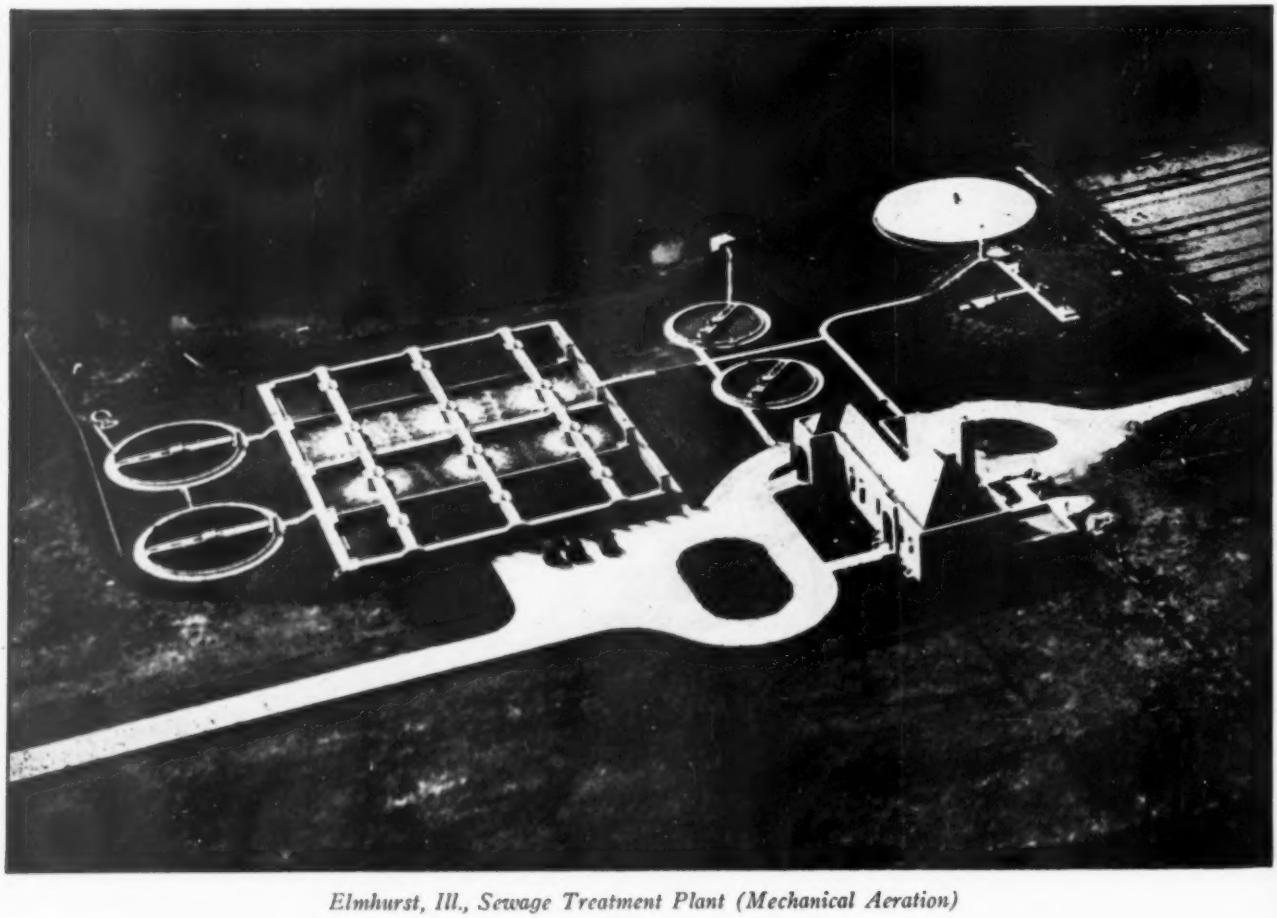
PLANT	Sewage Flow mgd.	AIR: Cu. Ft., Gal.	AIR: Cu. Ft. Per Pound of BOD. Removed	AIR: Suspended Solids Aeration Tank-ppm.	AIR: Aeration Period Hours	RETURN SLUDGE: Per Cent of Sewage Flow	RETURN SLUDGE: Suspended Solids %	SLUDGE INDEX: S. D. I.	SLUDGE INDEX: S. V. I.
Chicago, Calumet	82.4	0.35	500	2,860	4.0	22.4	1.55	1.93	52
Chicago, North Side....	196.	0.42	462	2,500	5.4	22.4	1.31	1.27	79
Cleveland, Easterly	91.3	1.10	1,420	2,240	6.6	20.9	1.11	1.35	74
Findlay, Ohio	2.295	0.69	840	1,420	5.5	25.9	0.51	0.66	151
Ft. Wayne, Ind.	17.6	0.99	835	2,320	8.6	27.	0.97	0.90	111
Gary, Ind.	21.5	0.41	910	1,350	3.9	32.5	0.45	0.98	102
Jackson, Mich.	9.15	0.60	650	3,020	..	15.	...	2.86	35
Marion, Ohio	3.76	0.62	907	3,000	4.0	31.9	1.08	1.75	57
Muskegon Hts., Mich. ..	1.18	0.47	345	900	6.3	41.1	0.43	1.0	100
New York, Wards Is. ..	184.	0.57	470	1,770	4.5	45.	0.48	0.59	170
Pasadena, Tri-City	9.63	1.73	1,450	1,100	6.9	12.	0.67	0.53	189
Rockville Center, N. Y.	1.99	2.0	2,180	740	5.0	3.5	2.70	2.63	38
Springfield, Ill.	9.2	0.64	950	1,580	5.45	28.	0.42	1.03	97

Concentration of Suspended Solids in Aeration Tanks: The control of the concentration of suspended solids in aeration tanks is one of the most important factors in operation. As shown in Table I, the concentration varies considerably with the individual plant, ranging between 500 and 3500 ppm. with values between 1500 and 2500 ppm. most common. There is no single optimum for all plants. In general, no more solids should be used than are needed to properly purify the sewage.

The concentration of suspended solids which should be maintained in the aeration tanks seems to be related to the volatile solids in the sewage. There is some evidence to show that if the percentage of volatile solids is high, the concentration of solids in the aeration tanks should be low since sludge with a high volatile content is bulkier and settles less readily than one with a high ash content and may therefore yield a poorer effluent.

Sludge with a high percentage of volatile matter is apt to be more active biologically than one with low volatile solids and if the total suspended solids in the aeration tanks are high, it may be difficult to maintain aerobic conditions especially in the summer months. Conversely, with lower volatile solids, higher concentration of solids may be carried in the aeration tanks.

Within an individual plant, the concentration of solids may vary 500-1000 ppm. from time to time. Sometimes this variation is intentional because of seasonal or



Elmhurst, Ill., Sewage Treatment Plant (Mechanical Aeration)

special operating conditions. Sometimes, it is unintentional, as for example, a concentration of suspended solids, much higher than usual may be caused by heavy storms or by the necessity of temporarily storing sludge in the system.

Aeration Period: The aeration period may usually be varied only within very narrow limits unless extra tank capacity is available. When several aeration tanks are in use, one or more of them may be removed from service in order to reduce the detention period in the others. In practice, the most common aeration period is 4-6 hours.

Long periods usually produce a high degree of purification with oxidation of nitrogen to nitrates. Since high nitrates stimulate the growth of algae and other aquatic plants, they may be undesirable in the outlet water course. With long aeration periods, however, the activated sludge process is less upset by shock loads and the plant is easier to operate. With short aeration periods, the process is more sensitive to sudden change and the plant is more difficult to operate.

Rate of Sludge Return: The rate of sludge return is usually expressed as a percentage of the sewage flow. For example, if the sewage flow is 10 mgd. and the return sludge rate is 25 per cent, the volume of return sludge would be 2.5 mgd. and the total volume passing through the aeration tank would be 12.5 mgd. Usually the sludge return rate varies from 20 to 45 per cent.

The concentration of solids in the aeration tank is controlled by the amount of excess sludge drawn off for disposal or wasting. Within limits, the rate of sludge return is not usually important as a high rate means thin sludge returned and a low rate means a heavy sludge. It is the pounds of solids returned to the aeration tank, which must be controlled, rather than the volume.

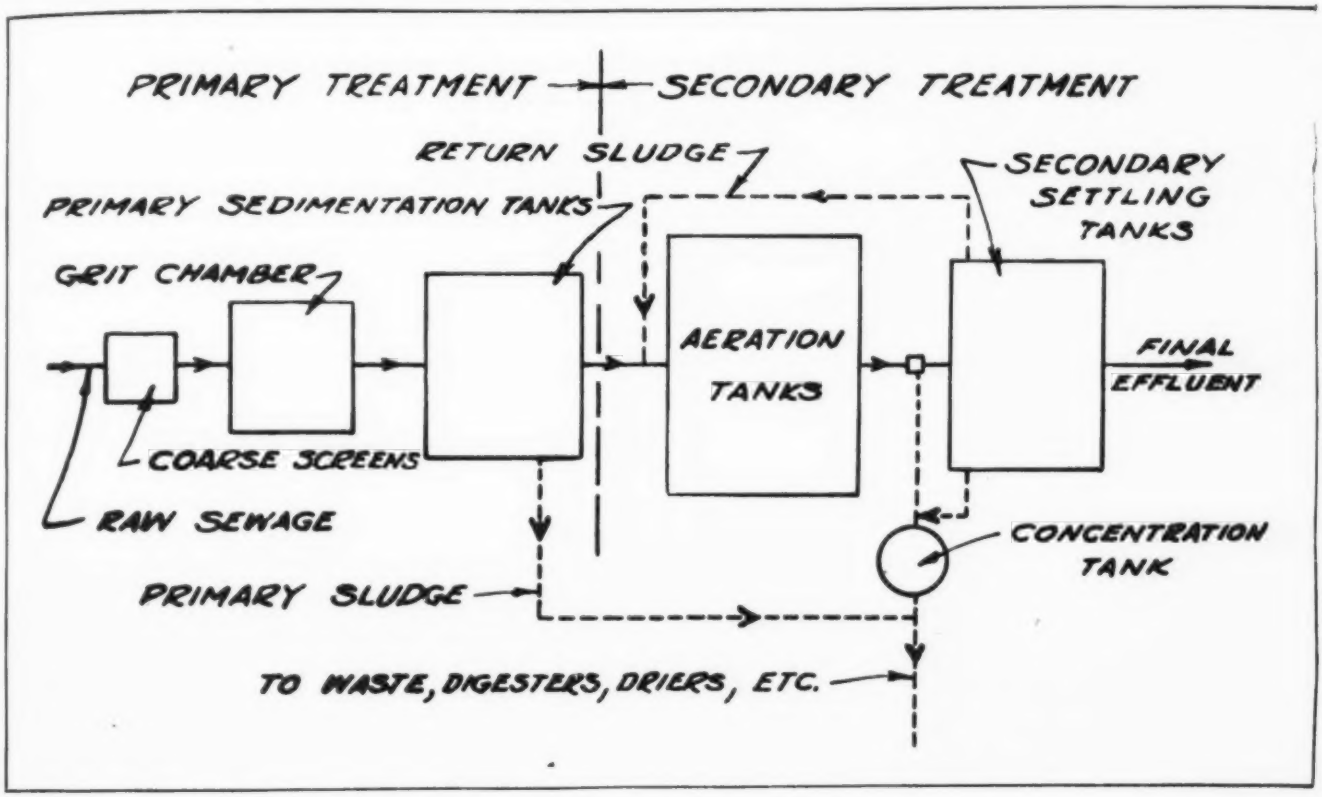
It is very important, however, to keep the solids fresh and the return rate should be high enough to avoid stale sludge. Returning sludge at a rate higher than the scrapers can bring it to the sump may mean circulation of aeration liquor. At Wards Island, where excess sludge is concentrated in separate tanks, the final tanks are kept as free from settled sludge as possible. Final settling tanks should not be used for sludge storage.

Condition of the Sludge: The condition of the sludge which reflects the success of the operator in controlling the environment is generally determined by its appearance and odor, settling characteristics and by microscopic examinations.

Fresh, well-conditioned activated sludge is brownish in color turning black as it becomes septic. It normally has a characteristic musty odor when fresh but becomes foul and sour when allowed to stand in the absence of air. The floc of good quality sludge is moderate in size and the water surrounding it on settling is clear and colorless.

The settling characteristics of sludge have considerable value in controlling operation and may be expressed in several ways. Theriault in 1920 called attention to the value of the "sludge ratio" as determined by dividing the parts per million of suspended solids in the aeration tank by the volume in milliliters occupied by the sludge after settling one liter of liquor for a period of 15 and 30 minutes. No single time was proposed and little or no practical use was made of the suggestion in the operation of activated sludge plants. Donaldson in 1931 proposed the "sludge index" for a practical routine test and computed it by dividing the percentage of aeration tank suspended solids by weight times 100 by the volume of sludge settled in 30 minutes, also expressed in per cent. Sludge index values above 1.0 were considered satisfactory for normal operation. Later experience has shown that some plants, such as Wards Island, may operate satisfactorily with an index as low as 0.50. In 1934, Mohlman proposed that the sludge index be defined as the volume in milliliters occupied by one gram of sludge after 30 minutes' settling and calculated by dividing the volume of sludge in per cent after 30 minutes' settling by the weight of suspended solids in per cent. With this index, values less than 100 are considered satisfactory. The Mohlman index (now known as the Sludge Volume Index) may easily be converted into the Donaldson index (now known as the Sludge Density Index.)

$$\text{S.D.I.} = \frac{100}{\text{S.V.I.}}$$

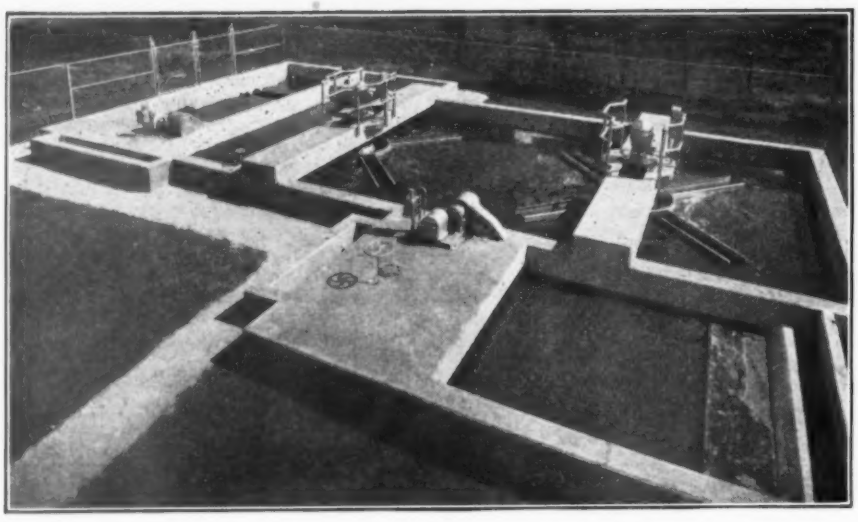


Flow Sheet—Activated Sludge Process

It is immaterial which index is used since all are based on the relation between the volume of settled sludge and the weight of suspended solids.

The index varies with the volatile solids content in such a way that the higher the volatile solids, the poorer the sludge index. No single value may be considered as critical for all plants but should be determined for each individual one. The use of the index is helpful in control of the aeration process because it indicates when trouble is approaching and gives the operator a feeling of security when the index consistently shows a well-settling sludge.

The microscopic examination of activated sludge to determine the numbers and types of organisms is a valuable aid to plant control especially where the condition of the sludge is variable. A compact floc with abundant stalk ciliates, few flagellates, and very few filamentous bacteria indicates a good sludge. Diffuse floc, many flagellates and amoebae, few ciliates, and a preponderance of filamentous forms means a poor settling sludge. The frequency of microscopic examination will depend upon



Mechanical Aerators at McHenry, Ill., Sewage Treatment Plant

the individual plant. When the sludge appears to be well conditioned, an occasional examination is sufficient but when there is reason to suspect trouble, daily examinations may be necessary.

Sampling

In order to control the process and determine accurately the operating results, as many samples as practicable should be collected at regular intervals throughout the 24 hours of the day. The purpose of collection of samples of sewages and effluents is to obtain a representative sample of the liquid for use in making a laboratory examination. The great variety of conditions under which collections must be made make it impossible to set up a fixed procedure.

The standard method comprises collection of composite samples over two 12 or one 24-hour period. Individual portions should be collected at least every hour and mixed at the end of the sampling period or combined in a single bottle as collected. A final volume of 2 to 3 liters is generally sufficient for sewages and effluents. It is desirable to combine individual samples in volumes proportional to the volume of flow.

All samples should be analyzed as soon as possible after collection and kept in a cooler until analyzed.

Grab samples, except for the dissolved oxygen determinations and for bacteriological examination, are not satisfactory.

Routine Tests

Certain routine tests are particularly helpful in controlling operation. Determinations of dissolved oxygen and suspended solids in the aeration tank are used to control the amount of air used and to maintain the proper suspended solids concentration. Settling tests on aeration tank effluents are needed together with the suspended solids to calculate the sludge index. Centrifuge tests are used as a rapid check on the concentration of sludge to control wasting of sludge. The depth of sludge or sludge blanket in concentration tanks is also a valuable aid in controlling the wasting of sludge. The use of the microscopic examination has already been mentioned. Along the coast, the determination of chlorides in the raw sewage is helpful in ascertaining the leakage of tide water into the sewerage system. Wide variations in pH values indicate discharges of industrial wastes.

Routine laboratory analyses useful in plant operation include the following:

Raw and settled sewage
- Biochemical oxygen demand
- Suspended solids
- Volatile suspended solids
- Organic nitrogen
- Ammonia nitrogen
- Settleable solids (by vol.)
- pH
- Chlorides

Activated sludge effluent
- Biochemical oxygen demand
- Suspended solids
- Volatile suspended solids
- Organic nitrogen
- Ammonia nitrogen
- Nitrate nitrogen
- Nitrite nitrogen
- Dissolved oxygen

Aeration tank effluent
- Suspended solids
- Settleable solids (by vol.)
- Dissolved oxygen

Return sludge
- Suspended solids

Primary and waste activated sludge
- Total solids
- Volatile solids

Tests such as the suspended solids, BOD., and nitrogen determinations are not used directly in plant control as the time required to make them is too long. They are extremely useful in giving an overall picture of the efficiency of treatment. The suspended solids and BOD. determinations are particularly valuable in showing the progress of purification through the plant and the work done by the individual units.

Disposal of Excess Activated Sludge

Because of the high moisture content of excess activated sludge, it is necessary to concentrate it before disposal. A common method of thickening it is to return it to the raw sewage so that the activated sludge solids are removed with the sewage solids in the primary settling tanks. Theoretically, the activated sludge floc should help clarify the sewage and cause better removal of suspended solids in the primary tanks.

If, however, the excess sludge is light, and primary settling period is too short, there is some danger of poorer settling portions passing through the primary settling tanks and tending to build up in the aeration system with a consequent deterioration in the quality of the sludge. When the excess sludge settles well, discharge of the sludge to the primary tanks at a low uniform rate is reasonably satisfactory if the sludge is removed frequently from the primary tanks. Success probably depends largely on the volatile solids content of the sludge. Low volatile solids mean rapid settling and satisfactory removal of the sludge in the primary tanks. High volatile solids mean poor settling and passage of sludge through to the aeration tanks.

Separate concentration tanks are used at many activated sludge plants to thicken either aeration tank effluent or return sludge. Some operators believe that the fresh aeration tank effluent concentrates better than the stale return sludge. In any event, the effectiveness of the concentration will depend to a considerable extent upon the percentage of volatile solids.

The concentrated sludge may be disposed of in many ways, such as: digested, dried and used for fertilizer, dried and incinerated or barged to sea. Pearse reported that about 90 per cent of the activated sludge plants disposed of excess activated sludge in separate sludge digesters.

Purification Obtained

An important characteristic of the activated sludge process is the high degree of

Tallman's Island Sewage Treatment Plant, New York City (Diffused Aeration)

purification which may be obtained. So much of the suspended solids and colloids may be removed that under ordinary circumstances, the settled effluent will be clear and contain but little suspended matter. The removal of suspended matter and BOD. varies from 85 to 97 per cent. As shown in Table II, the average removal of suspended solids and BOD. from twelve representative plants was more than 90 per cent.

At Wards Island, the average removal of bacteria growing on agar at 37° C. has been 98 per cent and of members of the coliform group, 99 per cent. The number of bacteria remaining, however, usually make chlorination necessary for disinfection where the effluent of an activated sludge plant is discharged in the vicinity of bathing beaches or shellfish layings.

High volatile solids content of the aeration solids appears to be a frequent cause of bulking, particularly in the summer. Relief is commonly obtained by a rain where the sewage is collected in a combined system.

The correction of bulking seems to depend upon a restoration of balance between oxygen demand and supply. This may be done by: (1) increasing the air supply; (2) adjusting the suspended solids in the aeration tanks, reducing them if they are too high and increasing them if necessary; (3) decreasing the sludge activity by the addition of chlorine; (4) bypassing part of the sewage flow if possible, and (5) evening out the flow of industrial waste if overloading is caused by intermittent discharge.

TABLE II
Chemical Analyses

PLANT	SUSPENDED SOLIDS				BOD.			
	Raw Sewage ppm.	Settled Sewage ppm.	Final Effluent ppm.	% Removal	Raw Sewage ppm.	Settled Sewage ppm.	Final Effluent ppm.	% Removal
Chicago, Calumet	129	...	12	92	92	...	9	90
Chicago, North Side	139	...	10	93	115	...	6	95
Cleveland, Easterly	239	165	12	95	148	106	13	91
Findlay, Ohio	427	90	11	97	405	121	21	95
Gary, Ind.	302	95	10	97	129	63	9	93
Jackson, Mich.	191	141	17	91	122	118	7	94
Marion, Ohio	241	104	12	95	145	98	9	94
Muskegon Hts., Mich.	305	134	69	77	357	193	52	86
New York, Wards Is.	204	...	20	90	167	...	14	91
Pasadena, Tri-City	303	...	27	91	149	...	13	91
Rockville Center, N. Y.	284	146	25	91	288	160	41	86
Springfield, Ill.	132	81	8	94	103	74	8	92

Sludge Bulking

Good quality activated sludge settles rapidly and a tendency toward slower settling and a poorer sludge index is an early sign of deteriorating sludge quality. As the floc particles increase in size and decrease in density, the depth of sludge or the sludge blanket in the final settling tanks increases until natural currents carry the solids over the weirs with the effluent.

This bulking or swelling of the sludge in volume is associated with loss of sludge activity and is characterized by a low settling rate and by a very poor sludge index. Filamentous growths such as Sphaerotilus are usually present in the stringy, deflocculated sludge. These organisms, however, are probably symptoms of a sick sludge, rather than a cause. Many causes have been given for bulking but the most important are too high or too low concentration of solids in the aeration tanks, insufficient air, overloading or very high volatile content of the suspended solids.

If the concentration of suspended solids is permitted to increase to such a point that aerobic conditions are not maintained throughout the aeration tanks, bulking may occur. Insufficient air is an important cause. If the concentration of solids decreases to about 500-800 ppm., a critical range is reached where very poor settling results. A further decrease in aeration tank solids yields a sludge which settles very rapidly.

Activated sludge may become sick by being overloaded; that is, by absorbing more decomposable organic matter than the available oxygen will oxidize. A good sludge may deteriorate by the addition of an abnormally strong sewage and will be overpowered if overloading is long continued. Overloading is often caused by large amounts of industrial wastes.

Chlorination of returned sludge has been successful in combatting bulking at a number of plants. The amount of chlorine used depends upon the concentration of solids and at Lima, Ohio, the dosage averaged 8.5 ppm. for each per cent of suspended solids in the returned sludge. In some cases, treatment with chlorine has not been successful.

Rising Sludge

Another operating problem is the occasional rising of large masses of sludge to the surface of final settling tanks. This may occur when nitrification is high and in the absence of oxygen the nitrates in the sludge blanket are decomposed to form nitrogen gas. The bubbles of gas will carry sludge masses to the surface. This condition is quickly corrected by reducing the amount of air applied. Increasing the sewage load or reducing the aeration tank solids in the unit causing the trouble is also said to be helpful.

Rising sludge may also occur as the very dense sludge in a final settling tank or concentration tank becomes septic. The gases formed become entrained in the sludge and carry it to the surface. The septic sludge must be removed and the sludge blanket kept low to prevent septicity. Failure of the sludge collectors to keep the tank bottom clean during warm weather is a common cause of this trouble.

Modifications of the Activated Sludge Process

By varying the air supply, the aeration period and the amount of returned solids, any degree of purification between sedimentation and conventional activated sludge may be obtained. For partial treatment, low air supply and small tank capacity are sufficient. Greater air supply and tank capacities will permit more complete treatment. Where conditions warrant, a high rate activated sludge offers a means for substantial economies in construction and operating costs. It is emphasized, however, that the type of treatment depends upon the degree of purification required. Where the highest degree of purification is necessary, conventional activated sludge should be used.

To illustrate the effect of varying some of the factors in the activated sludge process, data from several plants are presented in Table III.

Starting with plain aeration at Indianapolis, 59 per cent removal of BOD. was obtained in 6.4 hours. With very low aeration tank solids and a short aeration period at Jamaica, 70 per cent BOD. was removed and by increasing the solids, a slightly better effluent was produced. At Rockville Center, longer aeration with moderately low solids yielded 86 per cent removal of BOD. and at Bowery Bay, a short aeration period with high suspended solids produced an effluent of the same quality expected from the conventional activated sludge plant.

In varying from the conventional method of operation, the activated sludge process becomes more sensitive to shock and fluctuations of load and flow, and requires much more careful supervision.

If any conclusion can be drawn from a paper of this kind, it is that because of factors such as differences in characteristics of the sewage and variations in flow, each activated sludge plant is different from any other. No arbitrary rules for plant operation can be safely set up beforehand and many of the variables can be fixed only by experience.

Mention should be made of two excellent reviews of activated sludge operation. The comprehensive report of the Committee on Sewage Disposal of the American Public Health Association, of which Langdon Pearse was Chairman, was published in the *Sewage Works Journal* 14, 3, 1942. W. H. Wisely has presented additional data in a paper published in the *Sewage Works Journal* **15**, 909, 1943, and reprinted in the June, 1944, issue of *Water Works and Sewerage* (Ref. & Data section). Some of the information presented in this paper has been taken from these sources.

TABLE III
Modifications of the Activated Sewage Process

Plant	Date	Aeration Period Hours	Air Cu. Ft. Per Gal.	Sludge Returned %	Aeration Tank Solids ppm.	BOD. % Removed
Indianapolis	1942	6.4	0.49	0.0	156*	59
New York, Jamaica	Sept., 1944	2.28	0.29	16.0	365	70
New York, Jamaica	June-Aug., 1944	2.35	0.32	27.0	630	71
Rockville Center, N. Y.	1942	5.03	2.0	3.5	740	86
New York, Bowery Bay	1942-43	2.6	0.59	46.0	1800	90
Chicago, North Side	1936	3.0	0.37	21.7	...	91

*Suspended Solids—Settled Sewage.

CHICAGO PUMP COMPANY

2349 Wolfram St., CHICAGO, ILLINOIS

Complete Process and Pumping Equipment for Sewage and Waste Treatment

Fig. 2959—Aeration tank with diffusers operating. One raised for cleaning.

Swing Diffusers—Controlled aeration for the Activated Sludge Process. For towns of 4,000 and up. Diffuser tube assembly can be raised to tank walk. Simple regulation of air supply from tank walk. Tube cleaning without dewatering tanks or interrupting operation.

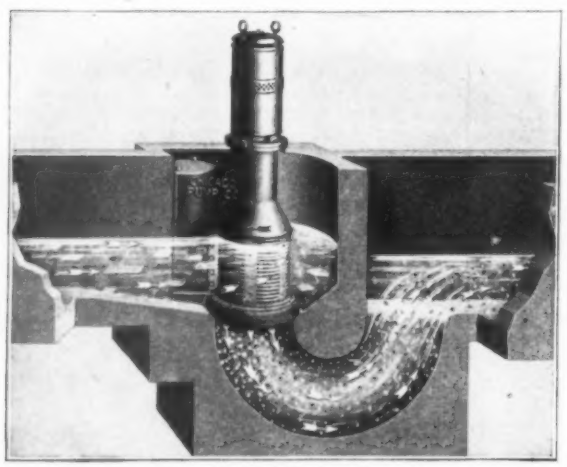


Fig. 2202—Comminutor

Eliminates screenings and screenings disposal — No burial; No incineration. Cuts coarse sewage matter into small settleable solids without removal from the channel. Ask for Bulletin 185.

Fig. 2504—Vertical Open-Shaft Non-Clog Pump

Universal Flexible Couplings in shaft compensate for misalignment. Ask for Bulletin 126.

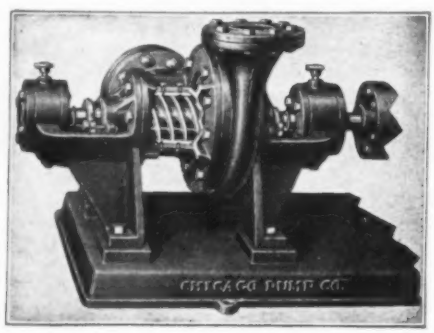
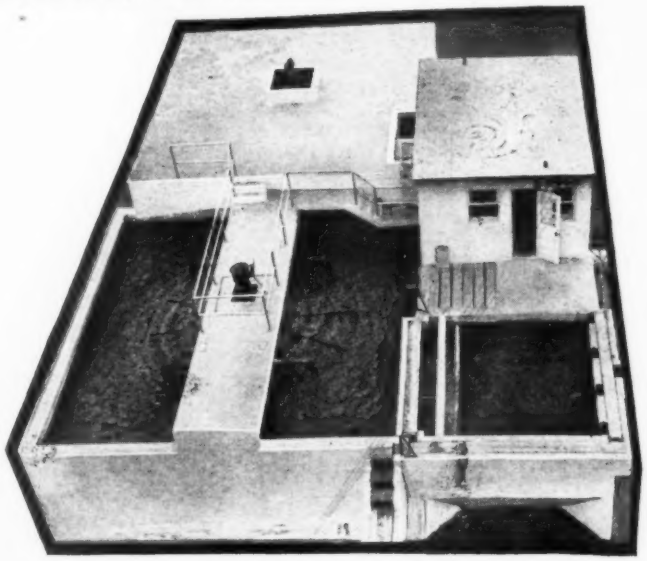


Fig. 1860—Scru-Peller Primary Sludge Pump

Screw conveyor in the suction ahead of the impeller. Stellited cutters prevent clogging. The capacity can be varied instantly. Ask for Bulletin 190.



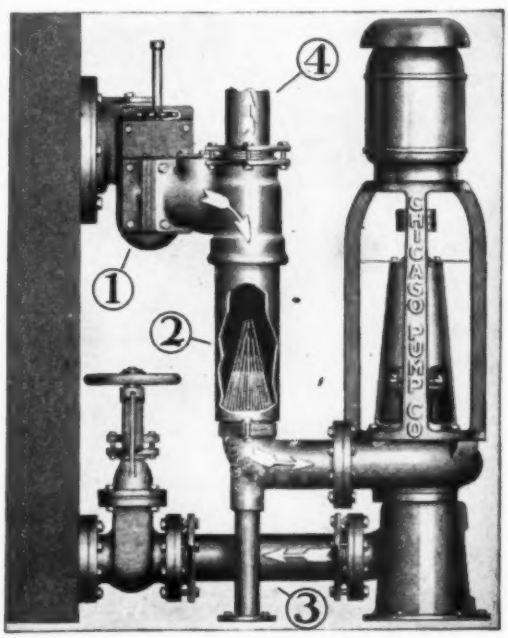
Chicago "Package" Sewage plants are ideal for small communities, industrial plants, airports, housing developments and institutions because they were specifically developed for small populations of 100 to 5000. Properly designed these plants can handle industrial, cannery and other wastes as well as the usual community sewage.

They require a minimum of operating supervision and produce a sparkling clear effluent. As they are free from flies, foul odors and unsightly appearance, location near dwellings is entirely feasible.

Operator training by Chicago Operating Sanitary Engineers is provided with each plant. Local operators without previous sewage treatment experience operate existing plants and perform other municipal duties.

Ingenious automatic features of Chicago Package Plants simplify operation and assure successful performance. Aeration and clarification are performed in a single tank with positive, automatic sludge control. One sludge setting covers a wide range of sewage flows and strengths.

Initial cost of Package plants is low and they are inexpensive to operate. Since 1934 over 100 of these plants have been installed and are successfully operating.



The FLUSH-KLEEN pump cannot clog because it is designed so that no solids can reach the impeller. Sewage flows through inlet pipe (1). Solids are retained on screen (2). (3) Strained sewage flows through idle pump to wetwell. As pump switches on, Checkvalve closes, sewage on strainer is backwashed and carried off through outlet pipe (4).

SLUDGE DENSITY CONTROL

With Particular Reference to Return Sludge Chlorination

By JOHN A. TAPLESHAY

Manager, Installation & Operation Dept., Chicago Pump Co., Chicago, Ill.

IN THE past six years the author has had the opportunity of supervising the initial operation of more than 50 activated sludge sewage treatment plants of various sizes and types in all sections of the United States. These plants ranged in size from small "package" combination aerator clarifier plants, treating 30,000 g.p.d. to conventional diffused air plants treating from 0.5 to 20.0 m.g.d.

The Sludge Index

"Sludge Index" is the term used to express the settleability of the suspended-solids and, therefore, density of the sludge after a given settling period.

$$\text{S.I.} = \frac{\%\ \text{Settleable Solids}}{\%\ \text{Suspended Solids}}$$

To most operators of activated sludge plants the control of the sludge index to insure proper settling and clarification ranks high among the problems in plant operation. Use of the sludge index as an operational control measure has become almost universal since it was first proposed by Donaldson in 1931 and later by Mohlman[1] (1934) in a modified form. To most operators it provides one of the surest means of determining the sludge conditions. The index of any activated sludge is dependent upon four principal factors which will vary from plant to plant. These factors are: (a) the physical characteristics of the plant, (b) the strength and characteristics of the sewage, (c) the concentration of solids in the mixed liquor, (d) the rate of return sludge.

The physical characteristics of the plant, such as the type of aeration employed and the aeration period, have a most important bearing on the index. Plants using mechanical aeration usually operate with indices three to five times higher than those using diffused air, principally because the concentration of mixed liquor solids in the diffused air plants can usually be maintained at a higher figure due to the more efficient aeration.

The most important factor which determines the index is, of course, the strength of the sewage, and since this varies considerably from plant to plant it is only natural that the proper index will vary likewise. Then, too, actual strength of the sewage in B.O.D. alone does not give the entire picture, for the characteristics of the sewage may have a decided bearing upon the proper index.

The concentration of solids in the mixed liquor usually has a definite bearing on the sludge index as in most cases the lowest index is obtained when the solids concentration is relatively high. This is true because a higher concentration of solids allows the plant to absorb increased loads or greater shocks with less disruption of sludge quality.

Unfortunately, many plants cannot maintain very high solids due to air limitations or for economic reasons.

Regulation of the rate of return sludge has a definite influence on the sludge index since by its regulation you balance the mixture of sludge with the load going to the aeration tanks. To have perfect control of the activated sludge process the rate of return sludge should be maintained at a constant percentage of the flow; however,

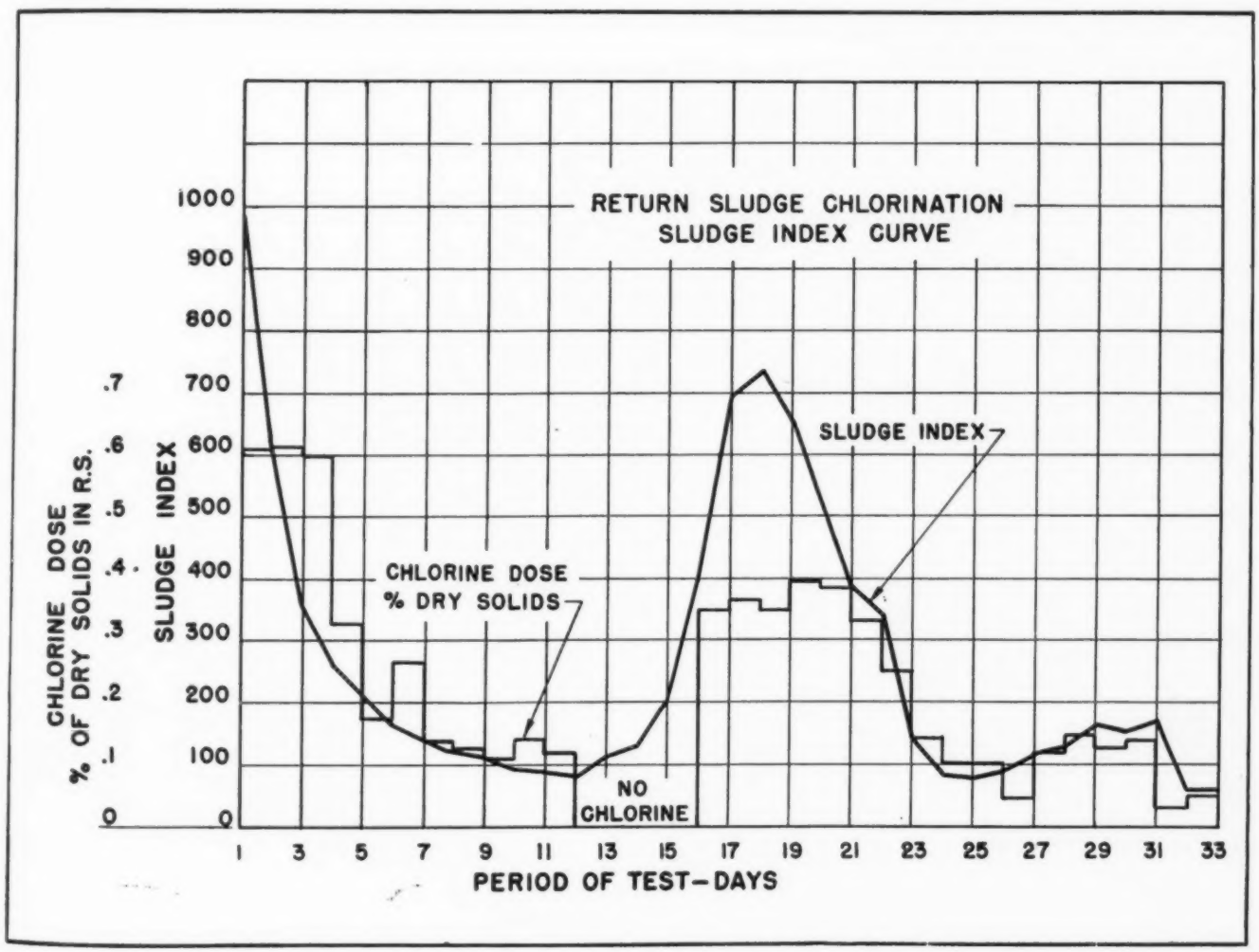


Fig. 1.—Effects of Return Sludge Chlorination on Sludge Index and Plant Performance

this is seldom done as most operators maintain a rate which will give what they consider the proper return for the *average* 24 hour flow.

In order to determine the index at which any plant performs best it is necessary to operate with the index at various points and compare plant efficiencies and performance at these various points. Having once established a normal or optimum index any abnormal increase of this figure can then be considered an indication of trouble, providing all other variables have remained constant.

An abnormal increase in the sludge index is quickly reflected in plant operation by poorly settling sludge, rising sludge blanket in the final tanks, and finally sludge pouring over the effluent weirs. It may or may not be possible to immediately determine the cause of the increase but in most cases adjustment of the air applied, the mixed liquor solids concentration and the return sludge rate, will correct the conditions. When all the ordinary corrective measures fail the index can usually be brought under control by the application of chlorine to the returned (recirculated) sludge.

Chlorination for Sludge Index Control

Chlorine has been employed in many instances for control of bulking sludge; in some cases its use has been successful; in others it has not. Most of the failures were due to inadequate control of the dosage or lack of information as to the proper dosage. A few users have based the chlorine dosage on the amount of dry solids in the return sludge, while more have figured the dose on a flow basis only.

During a period of three years while supervising initial operation of army sewage treatment plants, the author had the opportunity of doing considerable experimentation with the use of chlorine to control the sludge index and thus eliminate the trouble caused by bulking sludge.[3] Experiments were carried on at several different plants and sufficient data collected to determine a method of closely approximating the chlorine dose needed to control the sludge index and at the same time avoid over-chlorination.

Without going into complete detail of the experiments conducted, it was found that chlorine, when applied to the return sludge at a point which allowed at least 2 minutes' contact period and in a dosage based upon the sludge index and the weight of dry solids in the return sludge, would result in a definite predictable improvement in sludge index. Figure 1 shows a typical curve, taken from one of the experiments at an army camp, in which the sludge index was very high at the start of chlorination but was reduced materially in a few days. From this curve it can be seen that the chlorine dosage follows the index curve very closely. This fact is essentially the basis of a formula which was derived from the experiments. This formula is:

$$CD = F \times W \times S.I. \times .0000834$$

Where—

CD = Chlorine requirement in lbs./24 hrs. for each 100,000 gpd. of sludge returned.

F = return sludge flow in mgd.

W = suspended solids in return sludge in ppm. by weight—dry basis.

$$S.I. = \frac{\%\ \text{Settleable Solids}}{\%\ \text{Suspended Solids}}$$

As stated previously the necessity of using chlorine in the return sludge for sludge index control should first be established before it is put to use. While chlorine will control the index it must be remembered that it will increase the cost of operation somewhat, and if ordinary corrective measures will give comparable results they should be employed. In general, if the increase in index has been caused by a temporary unbalancing of the plant due to a lapse in control it is better to first try to restore the balance by routine adjustments, since this method will serve best to acquaint the operator with the effectiveness of such adjustments. If the increase in index has been caused by an overloaded condition which cannot be relieved by ordinary adjustments in control measures, chlorine can be advantageously used.

Point of Application and Amounts

The chlorine should be introduced into the return sludge at a point which will allow *at least 2 minutes'* contact period before it mixes with the primary effluent. This means that in most plants it will be introduced between 120 and 240 feet from the point of mixing with the primary effluent, since the velocity in the average return sludge line or trough is between 1 and 2

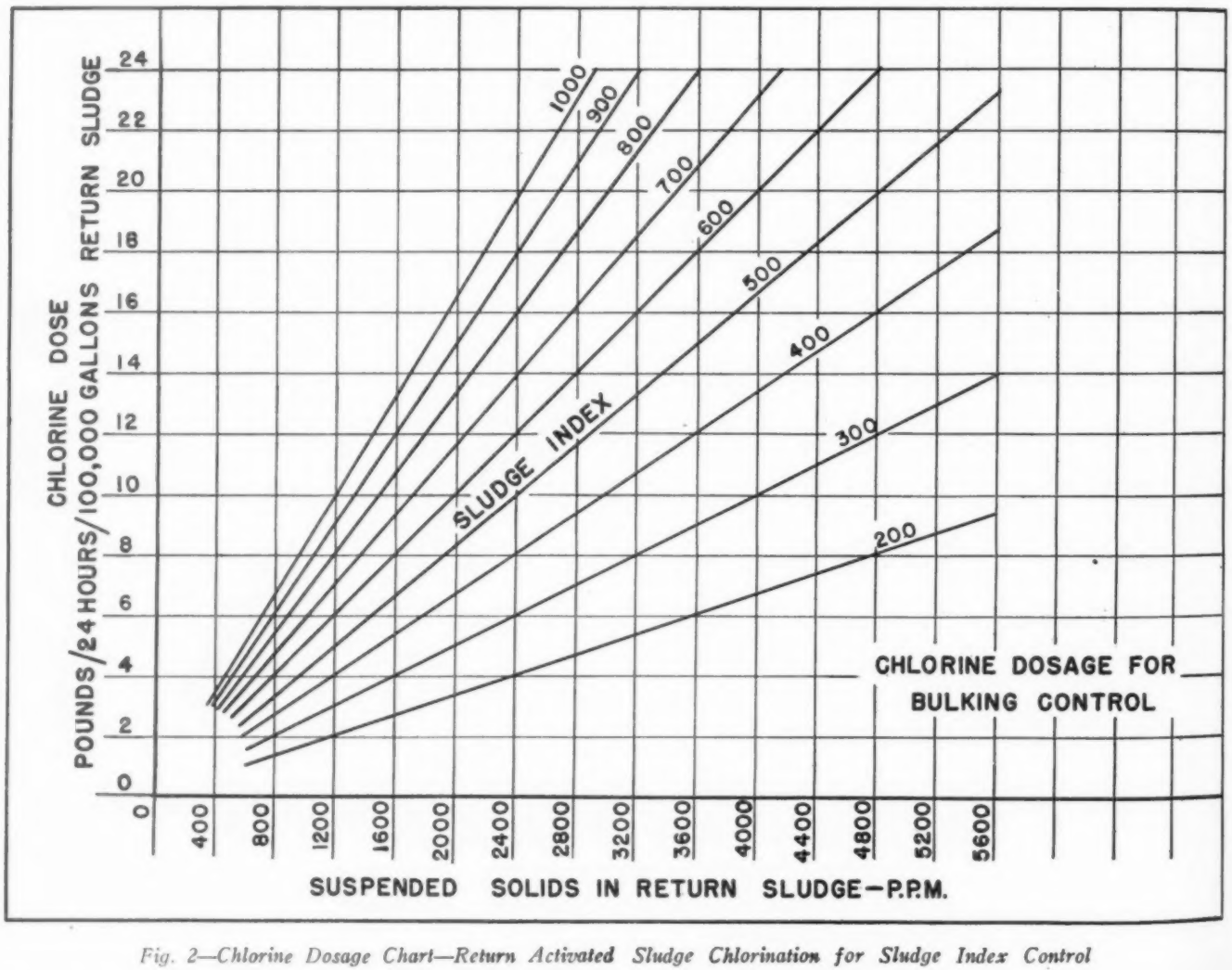


Fig. 2—Chlorine Dosage Chart—Return Activated Sludge Chlorination for Sludge Index Control

feet per second. Where it is not possible to introduce the chlorine into the return sludge line it can be applied in the common sludge hopper where return from the individual final tank hoppers is made.

The amount of chlorine to use can be calculated from the foregoing formula or taken directly from the curve shown in Figure 2. In either case, since the dosage is based upon the solids (dry basis) in the return sludge, the suspended solids in the return sludge should be obtained from a 24-hour composite sample. This is necessary since the suspended solids in the return sludge will vary throughout the day, and a grab sample will give an erroneous figure. Also to obtain best results the rate of return throughout the chlorine dosing period should be kept at a constant percentage of the flow. This means that regulation of the return sludge rate is necessary, especially during the low flow period at night.

The chlorine dosage as shown in Figure 2 is based upon a return sludge rate of 0.10 m.g.d. so that actual dosage to apply can be calculated as follows:

$$\frac{\text{Actual Rate of R.S. (MGD)}}{0.10} \times \text{Pounds of } Cl_2 \text{ as shown on graph} = \text{Dose to apply. (Lbs. per 24 hrs.)}$$

Reaction to Chlorination

When chlorine is first applied to return sludge there is usually a reaction within 12 hours. The first indication of this reaction is a clouding of the final effluent (a murky effluent) which is most pronounced when the index to start is very high and the mixed liquor solids very low. As chlorination is continued the index drops rather rapidly, the solids build up and the turbidity of the effluent decreases. Usually a decided improvement in the index is apparent within three to four days. Keeping a record graph similar to that shown in Figure 1 will prove of considerable value in following the effects of chlorination and evaluating the results.

While chlorination is in progress it is seldom necessary to re-adjust the dosage from day to day even though the sludge index is decreasing. This is true because when chlorination is started the solids in the return sludge are usually low and one of the aims of chlorination is to increase these solids. As chlorine is applied the lowering of the index allows the sludge to settle and compact more, thus rendering a more concentrated return sludge. In effect, even though the chlorine dose on a poundage basis remains constant, the amount fed on the basis of per cent of dry solids in the return sludge decreases.

Chlorination should be continued until the normal index has been obtained by which time the sludge character will have improved and the chlorine dosage will have been reduced. If the original upset has been due to a condition of short duration the chlorination can be discontinued, as the improved sludge will then handle the normal flow conditions. If the causes of the original upset are still present it may be necessary to continue chlorination as long as the cause exists. In either case, it is worth a trial to discontinue chlorination and observe the result. If the index immediately starts increasing it can be assumed that continued chlorination is necessary. In cases where continued chlorination seems advisable it is usually less costly to practice it, rather than to allow the index to follow a continuous cycle with chlorination being reinstated only when the index reaches a peak. In this case the amount of chlorine needed to reduce the index from its high point to normal will usually be greater than when continued dosing with a small amount is practiced.

Chlorination of the return sludge can, therefore, be utilized in a great many instances where control of the sludge index cannot be maintained by usual measures. By employing the formula suggested or making use of the chlorine dosage graph (Fig. 2), and following the procedures discussed and exercising ordinary judgment, upsets affecting sludge quality can be minimized if not completely eliminated.

References

[1]Mohlman, F. W. "The Sludge Index," *Sewage Works Journal*, 6, 1, 119 (Jan., 1934).

[2]Tapleshay, J. A. "Control of Sludge Index by Chlorination of Return Sludge," *Sewage Works Journal*, 17, 6, 1210 (Nov., 1945).

SLUDGE INDEX CONTROL BY CHLORINATION

Experiences at the Activated Sludge Plant of Tenafly, N. J.

By J. KENNETH ADAMS

Supt., Dept. of Sewerage and Sanitation
Tenafly, N. J.

THE growing interest in return sludge chorination for density control leads to this short account of its successful application at the Sewage Treatment Plant of Tenafly, N. J., which employs the activated sludge process.

Two recent articles by John A. Tapleshay in the November 1945 *Sewage Works Journal* and in the March 1946 issue of *Water and Sewage Works* gives concrete evidence of the value of chlorine in preventing sludge bulking and makes first attempt to put the chlorine dosage on a rational basis.

The Tenafly plant receives no industrial sewage of any importance. We have no primary settling tanks, the primary treatment comprising coarse and fine screening only.

There are no digesters. The waste activated sludge is dewatered on vacuum filters and dried in a Raymond Flash Dryer, and bagged for fertilizer, for which we have so far found a good market.

The plant is designed to handle 1.75 mgd. with a 5 hr. detention period in the aeration tanks. Air is supplied through diffuser plates.

The clarifier effluent is further purified by its passage through sand filter beds and is also chlorinated before reaching a brook, which feeds an important public water supply reservoir.

Experiences With Chlorination

Our first attempt to improve the sludge index with chlorine was in December 1939. Our point of application was a reaeration tank used principally for sludge storage. We chlorinated only half the return sludge and got no results. The experiment was continued by applying the chlorine at the wet well, where it came in contact with *all* the sludge but only after the sludge was mixed with the screened sewage. About 6 ppm. was used, calculated on the volume of the returned sludge. A definite improvement in index was noted after a week. The sewage flow was very low and there was no urgent need of heavier sludge, so we learned no more about the effect of using chlorine for the next five months. This time we were in the midst of high flows during a wet spring and needed every aid we could find to make the sludge settle in the final tanks.

In the meantime we had enlarged the plant and acquired a more suitable place to apply the chlorine, that is, at the air lift box where the return sludge from both final tanks is mixed before it proceeds a few feet further to join the sewage. The contact period before it is mixed with the sewage is only about a half minute, with another equal period before the mixture reaches the aeration tanks.

For several years we have used the Donaldson Sludge Density Index, (S.D.I) as it seems to us to be appropriate to have a rising index go with an increasing sludge density and an improving sludge quality. But it makes no difference at all which way the ratio of solids to settling is expressed. By many the Mohlman Index (S.V.I.) is used.

On the second try the chlorine machine was set at 18 lb. per day. This rate of application gave 1 to 3 ppm., depending on the return sludge volume which is varied from time to time.

In eight days the index improved from 0.43-D (234 M) to 0.89-D (112 M), the letter "D" expressing the Donaldson Index and "M" the Mohlman Index. Chlorination was then stopped and the index improved in the next seven days to 0.94-D (107 M).

This test convinced us that there was something to the chlorination idea, but we had several disappointments during the next two years and found that we got better results by using more chlorine, usually 4 to 8 ppm.

Chlorination Effects Continue After Discontinuance

The chlorine treatment seems to develop a condition that carries over for several days to a week from the time chlorination is stopped. Our results confirm Tapleshay's experience that a smaller dosage may be used to hold a given level than is required to bring the sludge up to the desired point once it has gotten into poor condition.

High Solids Give Better Results Than Low Solids at Tenafly, But Require More Chlorine

At our plant we carry higher than average suspended solids in our aeration tanks. Our best operating range is 3500 to 4000 ppm. We are less likely to run into a sludge condition requiring chlorine when we carry high solids than if we get down to 2000 to 3000 ppm.

For example, from July 11 to Nov. 25, 1945, there was no need to use chlorine to hold a satisfactory index (0.95) while our aeration tanks suspended solids averaged 4420 ppm. During the first six months of the same year the index averaged about the same (0.91) with solids averaging 2890 ppm., but it is important to note that from January to June we had an almost continuous sequence of rising and falling indices, requiring frequent chlorine applications.

I wish we could say that high aeration tank solids are the infallible remedy against declining sludge density, but the fact is that even with solids averaging 4500-5000 ppm. we have resorted to chlorine to maintain the index. With the high solids we discovered that it took 10 days to two weeks of chlorination to secure satisfactory results, while with solids ranging from 2500 to 3000 ppm. it usually requires only five days to a week.

This would seem to indicate that there is a definite ratio between the total weight of organic content in the sludge returned and the amount of chlorine required to correct that condition of the sludge which causes it to become voluminous and bulky. This seems to be a logical explanation; the larger quantity of sludge in the tanks being less responsive to the fixed chlorine dosage that we have been in the habit of using.

When the sewage flow is high, thereby reducing available settling time in the final clarifiers, it is important to keep the index up so that the sludge will settle out and be compacted quicker. At such times we might start chlorination when the index drops to 0.85 while for lower and more normal flows we would wait until it reached 0.60. In very dry weather and low flows we have had very satisfactory operation even with the index below 0.50, but under average conditions this would be a bulking sludge with us.

We usually stop applying chlorine when the index goes up to 1.10 or 1.20. Of course, the main object is to reduce sludge volume and when the flow is higher than normal, this is of special importance. Cutting in additional settling tanks (for those fortunate enough to have them) can be avoided in spite of higher flow rates if the sludge index can be kept at its optimum. Almost any sludge will settle in a final tank if there is no limit on tank capacity, but a high sludge index will give better overall performance than several additional tanks. The phenomenon of "rising sludge" is not covered in this statement because this is a different condition.

Now Trying More Scientific Chlorine Control

Until recently we applied chlorine at the same rate continuously from start to finish. The sludge return rate varied, making the dosage fluctuate between 3 and 8 ppm., averaging about 5 ppm.

Lately we have been following Tapleshay's suggestion (*W&SW*, March, 1946) of reducing the chlorine as the index improves, but have not yet decided to use a low dosage of chlorine continuously to maintain a good index. However, experience may prove this to be a very useful practice for us also.

We have tried much higher chlorination rates, up to 25 ppm., but the improvement does not seem to be accelerated by high dosages, and if prolonged for a couple of days, a noticeable turbidity in the clarifiers will result. It would appear that a moderate dosage and time for the cumulative but milder effect is a basic requirement for securing the optimum effect and economy. We do not know just where this limiting line is, because the results have been so good when averaging 5 or 6 ppm., calculated on return sludge volume, that we have not experimented any further.

Incidentally, we found a very noticeable decrease in spherotilis in the sludge during chlorination.

Of course, it is not always necessary to use chlorine to hold a good index. The causes of balking appear to be many and have been discussed frequently in the literature. The explanations are still rather obscure and it would seem that the phenomenon of why sludge settles or refuses to settle still offers a fertile field for exploration.

After our first couple of years of feeling our way along with this modern "elixir," chlorine, we have learned enough about its possibilities and limitations to enable us to use it confidently.

When used in quantities of 4 to 8 ppm. it has never failed us during the last four years if started within reasonable time after the sludge index begins to slide off. Improvement can be noticed in about two days, and the results desired are realized usually in less than a week. It will be noted also that we find chlorination is beneficial in cold weather, whereas others find it most helpful in warm, dry weather.

A typical example can be taken from our records starting Feb. 21, 1945, with a good index of 1.22, dropping in 11 days to 0.53. Chlorination at 4 ppm. (average) was started at 0.77, two days before the low point was reached. In eight days the index had recovered to 1.14 and continued to rise for two more days, reaching 1.23. Without the benefit of chlorine a decline then set in and a new cycle began.

Correcting a bulking sludge under our old operating technique was an expensive, heart-breaking, and long drawn out process, consisting of increasing the air as much as possible, and more important, of getting rid of almost everything in the system but the water. Almost any activated sludge plant operator will know what this means —lagooning, and what have you.

[Note—We have never enjoyed the ability to bypass the sewage because of the water supply situation.]

With high solids as our main standby for normal operation, we know we can depend on chlorine for an economical and rapid corrective for that very perplexing and disturbing phenomenon—sludge bulking.

It is as easy as going to the faucet for a drink of water. We just turn on the chlorine and watch the index improve, without having to resort to anything more drastic or expensive than this simple expedient.

WHAT LEAKS COST

SIZE OF OPENING	AIR		STEAM		WATER	
	Number of Cu. Ft. Wasted per Month 100 Lbs. Pressure	Total Cost of Waste per Month @ 10c per M Cu. Ft.	Number of Lbs. Wasted per Month 100 Lbs. Pressure	Total Cost of Waste per Month @ 60c per M Lbs.	Number of Gallons Wasted per Month 40 Lbs. Pressure	Total Cost of Waste per Month @ 15½c per M Gals.
1/2"	17,798,400	$1,779.84	805,000	$483.00	1,231,000	$192.00
3/8"	9,979,200	997.92	460,000	276.00	692,400	108.00
1/4"	4,449,600	444.96	203,000	121.80	307,700	48.00
1/8"	1,114,560	111.46	50,500	30.30	76,900	12.00
1/16"	278,640	27.86	12,750	7.65	19,200	3.00
1/32"	69,552	6.96	3,175	1.91	4,800	0.80

Courtesy M. B. Skinner Co

CLEANING AIR-DIFFUSION MEDIA

With Some of the Economic Considerations Involved

By JOHN J. WIRTS
Superintendent
Easterly Sewage Treatment Works, Cleveland, Ohio

THE PROBLEM of maintaining the porosity of air-diffusion plates and tubes used principally in conjunction with the activated sludge process and grease flotation and flocculation has been of growing concern to plant managers. The magnitude of the problem is increasing rapidly, due to two principal factors: (1) the widespread application of the activated sludge process during recent years; and (2) the increase of contributed industrial wastes incident to the war effort. Clogging is inherent with all diffusers required for efficient aeration of sewage. It follows, therefore, that such clogging must be accepted and that practical procedures must be developed to maintain efficient services. It is the purpose of this paper to discuss the need for and the process of cleaning diffusion media and to suggest a new scrubbing principle that has certain interesting possibilities.

Perhaps the best method of demonstrating the need for clean diffusion apparatus is by a dollars and cents comparison of air costs at increasing blower discharge pressures. It is the back pressure, created by the loss of head across the diffusers, that is solely responsible for higher costs of compressed air. In Table I the theoretical yearly cost of compressed air is computed for the Easterly Plant of Cleveland. The comparison is based on the use of 1.0 cubic foot of air per gallon of sewage, 6.7 mills per kilowatt hour for power, and a yearly sewage flow of 33,000 million gallons. On this basis an increase of one pound in blower discharge pressure can be evaluated to approximately $20,000. The cost of air per million gallons increased during the four year period from $2.68 to $3.56.

Table II shows the gradual rise, month by month, of the blower discharge pressure. The present rate of plate cleaning at this plant seems to be just enough to equalize the rate of clogging, roughly estimated at 0.4 pound per square inch increase in blower discharge pressure per year. Better still would be a gradual decrease in pressure from the built up average of 8.0 pounds per square inch for 1941 and 1942. For sewerage treatment plants in general it can be shown to be economically sound as a rule to begin a program of diffuser cleaning when the loss of head has increased 0.5 pound per square inch. This figure should be expected to vary from plant to plant, depending upon the cost of power at any particular plant. Cleaning cost should be more than offset by the decrease in power cost, otherwise there would be little advantage gained.

Fig. 1. Rubber Lined Acid-Soak and Rinse Tank for Diffuser Plate Cleaning
(The attendant wears rubber gloves and apron.)

Easterly Studies

Studies on diffuser plate cleaning was started in 1939 at the Easterly Treatment Works. Although this work began before there was any apparent need for cleaning, it was known that the character of sewage (high in iron salts and grease) was such that in due time the effects of clogging would become critical. Events subsequently have proved this assumption to be correct. Notable increases in blower discharge pressures were observed during the year 1940. Fortunately the plant was designed with the Burger removable cast aluminum plate manifolds, which made the clogged diffuser plates readily accessible for experimental purposes.

In the course of these studies, extensively reported in the *Sewage Works Journal*,[1] hundreds of plates were treated with various solutions, such as caustic soda, gasoline, muriatic acid, nitric acid and chromic acid. Previous investigators[2, 3] have been limited principally to the use of a loss of head measurement on fixed diffusers; these investigators being unable to accurately report the percentage recovery in porosity by treating procedures.

TABLE I—RELATION OF BLOWER DISCHARGE PRESSURE TO COST OF AIR

Year	Discharge Press. Lbs. per Sq. In.	K.W.H. Required per M. Cu. Ft. Air	K.W.H. Cost per M.G.	Yearly Cost[1]
1939	6.8	400	$2.68	$ 88,440
1940	7.1	463	3.10	102,300
1941	8.0	540	3.62	119,460
1942	8.0	531	3.56	117,480

TABLE II—BLOWER DISCHARGE PRESSURE
(Pounds per Square Inch)

	1939	1940	1941	1942
January	6.8	6.9	7.3	7.9
February	6.5	6.8	**	8.1
March	6.5	6.8	8.1	8.0
April	6.8	7.2	8.1	8.1
May	6.8	7.3	7.7	7.8
June	6.8	7.4	8.1	8.0
July	6.9	6.9	7.9	7.9
August	6.9	6.9	7.9	7.9
September	6.8	7.1	7.9	7.9
October	6.8	7.2	8.0	7.9
November	6.8	7.3	7.8	8.1
December	6.8	7.4	7.9	8.0
Average	6.8	7.1	8.0	8.0

**Plant out of operation part of month, omitted from average calculation.

The standard of comparison of rating of diffuser plates is permeability, which is defined as the number of cubic feet of air at 70° F. and 10 to 25 per cent relative humidity, that will pass through 1 square foot of diffuser area to the atmosphere, under a differential pressure through the diffuser equivalent to 2 inches of water when it is tested dry in a room maintained at a temperature of 70° and a relative humidity between 30 and 50 per cent. A precise determination of this value requires elaborate control of conditions and equipment. However, a more simplified procedure has been developed which has proved satisfactory for comparative purposes in testing plates.

An apparatus for permeability measurement was constructed

[1]Based on 1.0 cu. ft. of air per gallon of sewage, 6.7 mills per K.W.H. and yearly sewage flow of 33,000 M.G.
Note: Actual 1942 cost of power for blowers was $92,393 due to a rate reduction of 1.3 mills per K.W.H. by change in power source from a private power company to the Municipal Power Division.

after the type described by Beck.[3] It consists merely of a metal box for tightly holding the plate to be tested, an orifice meter for measurement of the rate of flow of air through the plate, and a draft manometer for measurement of pressure under the plate—i.e., the differential. The average test permeability of thirteen new diffusers was within one per cent of the permeability rated by the manufacturer. The maximum difference between test permeability and rated permeability for one plate was less than four per cent. In no case were air temperature and barometric pressure corrections applied. Relative humidity varied from 40 to 80 per cent with very little effect on the observed permeability. Damp or rainy days were avoided, as suggested by W. E. Holand.[3]

The functioning of the permeability apparatus should be checked by first testing with one or more reference plates of known permeability. Should the ratings not be normal, the apparatus should be checked for leaks. If there are no leaks the tests should be delayed until weather conditions are satisfactory.

Rubber gloves, rubber aprons and boots are provided the attendants for additional protection against chromic acid poisoning and strong caustic burns.

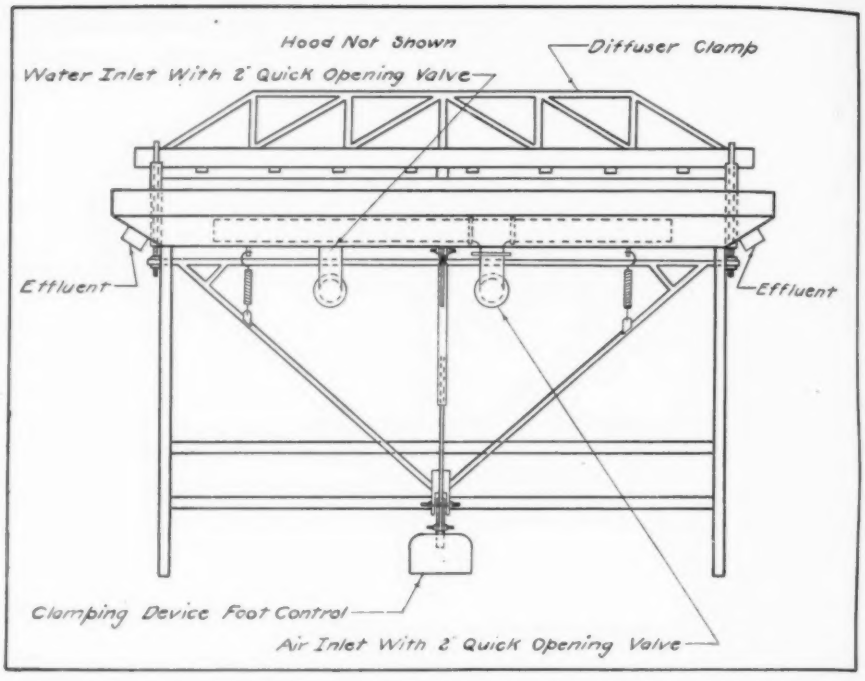


Fig. 2. Front View of Air-Water Wash Scrubbing Machine—Four Plate Capacity

Cleaning Equipment and Procedure

Twenty gallon crocks were provided for treating the diffusers, and a cylindrical rubber-lined steel soaking tank, as shown in Figure 1. The soaking tank was provided with water connections and a drain. Supports made of 3/8-inch rod covered with rubber tubing were hung in several of the crocks to hold the plates while the cleaning agent drained out after the treating period and prior to washing. The rubber-lined tank served as a storage tank for the drained, acid-soaking plates before the plates were transferred to the internal scrubbing machine (Figure 2), to be described later.

The method of cleaning consisted of three steps: (1) soaking the plates for several hours in a cleaning agent consisting of a 2 per cent solution of sodium dichromate in sulphuric acid, (2) allowing the cleaning agent to drain out of the plate, and finally (3) subjecting the plates to a thorough scrubbing with compressed air and water mixture.

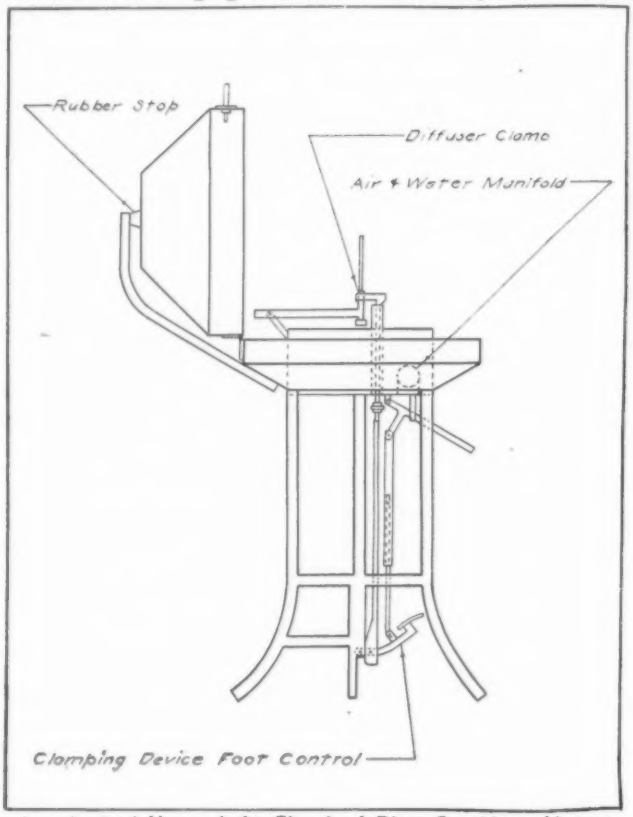


Fig. 3. End View of the Cleveland Plate Scrubbing Machine

Prior to development of the scrubbing machine it was necessary to rinse the plates in as many as six baths of water, in order to remove the bulk of the cleaning solution. Even with this practice some of the agents remained inside the pores of the diffusers, with the result that on batches of 1,200 plates the average percentage of recovery of porosity was between 70 and 75, as determined by the permeability apparatus. Experience with these plates indicated that the reduction of head loss was satisfactory, but upon a second cleaning, following a year of service in the aeration tanks, the residue remaining from the original cleaning was very difficult to remove. Since the clogging of the diffusers is not limited to the top surface, but penetrates into the interstices, it is essential that the interior of the diffuser be freed of all deposits, if the life of the diffuser is to be prolonged. The combination of compressed air and water was selected as the most readily available agents to remove the deposits.

The Internal Scrubbing Device

The machine sketched in Figures 2 and 3 and pictured in Figures 4 and 5 provides holders for four 12 in. by 12 in. by 1 in. standard diffuser plates, which are firmly held down by the foot control clamping device. Two 2-inch quick opening valves allow water, air, or both, to enter the manifold beneath the plates. The water is taken from a line under 70 pounds per square inch pressure and the air is from an air main operating at 8 pounds per square inch pressure. The duration of the scrubbing period is about one minute. During that time the valves are in an open position, forcing the mixture of water and air up through the diffusers in a violent manner. The wash water spills into the effluent trough and then to waste. A sheet metal hood shown in Figure 4 is hinged to the rear of the machine and folds down, enclosing the diffusers. The purpose of the hood is to protect the operator from acid spray.

Rubber gloves, rubber aprons and boots are provided the attendants for additional protection against chromic acid poisoning and strong caustic burns.

The operator easily judges the time necessary for proper scrubbing by the uniform appearance of air bubbles (Figure 5). At the proper moment the quick opening valves are closed and the clamp released. The completely cleaned plates are then ready for service in the aeration tanks.

During the year 1942, 4,800 diffusers were treated with a 2 per cent solution of sodium dichromate in sulphuric acid. After machine scrubbing, these were found to be within 90 per cent of their original porosity. Table III gives the typical results of cleaning an aeration tank containing 1,200 diffusers. Five batches of six plates were selected as representative. Their permeabilities when new varied from 39 to 43. The overall recovery after cleaning averaged 91 per cent. Similar results were obtained for tested plates from other aeration tanks.

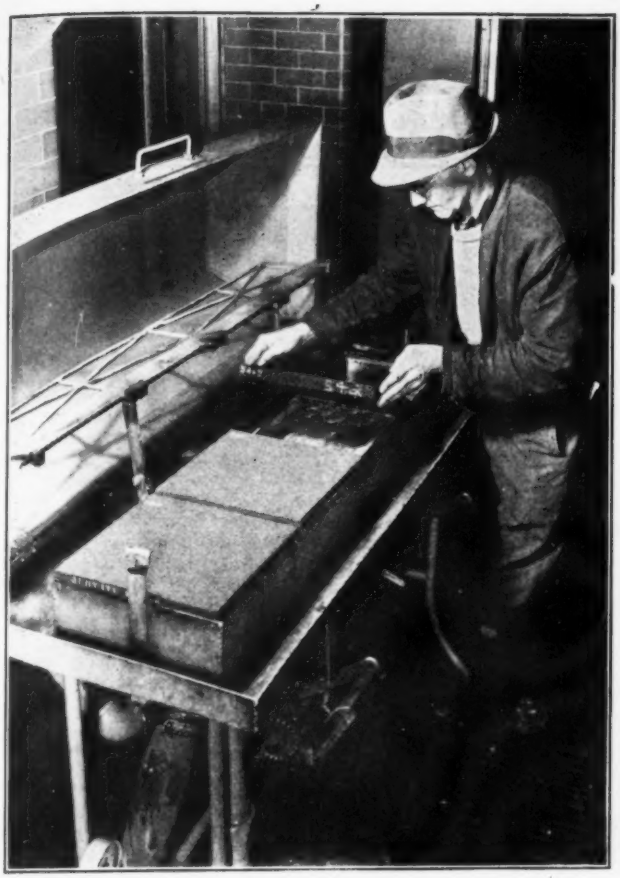


Fig. 4. The Plate Scrubber Being Loaded
(Ease in operation is provided by arrangement of clamping device in open position and quick opening water and air valve.)

TABLE III

TESTED PLATES FROM AERATION TANK No. 15			AFTER CLEANING
No of Plates Tested	Rated Perm. (New)	Permeability After Treatment	Per Cent Recovery
6	39	36	92
6	40	36	90
6	41	37	90
6	42	38	90
6	43	40	93
Ave.... 6	41	37.4	91

A deposit of fine silt is found in the effluent trough of the machine after several hours of service. Quantitative analysis of this deposit showed a silica content of 70 per cent on a dry basis, the remaining 30 per cent consisting of a combination of aluminum and iron oxides. Although this deposit is in quantity very small per plate, its presence is difficult to explain. The silica content was identified as rounded grains of sand and the aluminum oxide consisted of very small particles of the diffuser plate. The iron oxide was that portion of insoluble iron that remained after the acid bath. It is believed that the activated sludge carries the silt referred to previously, and under certain conditions this silt is deposited in the pores of the plates, together with accompanying solids.

The unit cost of cleaning diffusers for the year 1942 was estimated at 45 cents per plate. Approximately 36 cents of this amount is charged against the labor in handling, that is, the labor of removing the plates from an aeration tank, chemically treating, machine scrubbing and replacing in the aeration tank. Sulphuric acid, dichromate of soda, caustic soda (when necessary), and miscellaneous items were estimated at 9 cents per plate.

Discussion and Conclusion

The permeability apparatus as described is a very useful and necessary device in developing cleaning procedures. The necessary tests for measuring the results can quickly be run on the permeability apparatus without elaborate corrections for humidity and temperature.

Fig. 5. The Plate Scrubber in Operation at Partial Rate with Spatter Hood Raised
Note the clamping bar locked in place by the quick-trip foot pedal. Operator is holding air-water mix valve partially open. Uniformity of bubbling constitutes the check-up on porosity recovery. This observation follows the high pressure air-water wash.

In routine plate cleaning, the 2-per cent dichromate solution in sulphuric acid is recommended. In certain cases in which grease is the principal clogging material, a strong caustic solution can be used first, then followed by the dichromate solution.

The use of compressed air and water in connection with internal scrubbing practically restores the diffusers to their original porosity. This is particularly true on the second or third times that the diffusers are cleaned, because residual clogging material is removed each time after a service period and is not allowed to build up inside the diffuser plates. Merely washing out the plates by a stream of water or by immersion in water is not sufficient to remove all of the clogging material and to restore the diffuser plate porosity.

It is sound economy to clean diffusers when the blower discharge pressure increase equals one-half pound per square inch.

It has been demonstrated that aluminum oxide ("Aloxite") diffusers can be economically removed from the Burger type aluminum holders, cleaned and returned on a full plant-scale basis at an overall profit in power savings.

The cost of labor in handling the diffusers is roughly 80 per cent of the total cost of cleaning operations, which is 45 cents per unit of one plate.

The development of an apparatus utilizing the principle of pressure scrubbing, that could be used on fixed diffusers, with suitable solvents, would eliminate much of the labor cost which is principally for removal and return of the plates. Such an apparatus, if made portable, would prove of almost universal use in plants using diffused air.

References

(1) Willard F. Schade and John J. Wirts, Diffuser Plate Cleaning Versus Compressed Air Cost—*Sewage Works Journal* 14, 81-96 (January 1942).

(2) A. J. Beck, Diffuser Plate Studies—*Sewage Works Journal* 8, 22-37 (January 1936).

(3) W. E. Howland, Discussion of paper "Diffuser Plate Studies"—*Sewage Works Journal* 8, 485-488 (May 1936).

"Varec" THE GUARDIAN OF SEWAGE GAS CONTROL

THE PACE SETTER SINCE 1928

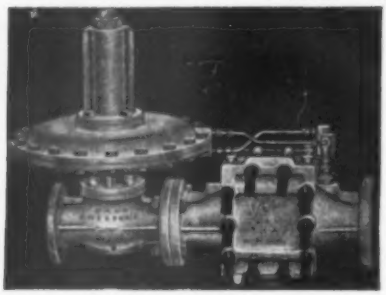


Figure No. 440

Sizes	2"	2½"	3"	4"	6"
Sh. wt.	125	140	160	200	260

← THE NEW "VAREC" *Approved* PRESSURE RELIEF AND FLAME TRAP ASSEMBLY

Unit consists of Diaphragm-operated Regulator. Flame Trap, and Thermal Shutoff Valve. Maintains a predetermined back pressure, passing surplus gas to Burner. Stops flame propagation. Patented telescopic flame trap element simplifies inspection and maintenance. Listed by the Underwriters' Laboratories for vent lines in oil tanks.

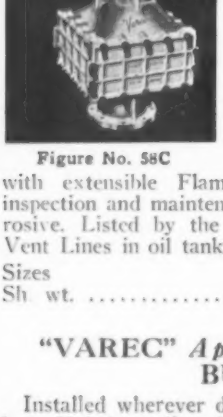


Figure No. 58C

"VAREC" *Approved* PRESSURE RELIEF AND VACUUM BREAKER VALVE WITH ← FLAME ARRESTER

Installed on digesters and gas holder domes, it affords emergency Pressure and Vacuum Relief and prevents flame entrance from atmospheric disturbances. Equipped with extensible Flame Arresting element for easy inspection and maintenance. Pure aluminum. Non-corrosive. Listed by the Underwriters' Laboratories for Vent Lines in oil tanks. Size 2" to 10".

Sizes	2"	3"	4"	6"
Sh. wt.	70	105	160	225

"VAREC" *Approved* WASTE GAS BURNERS →

Installed wherever disposal of surplus gas is a problem. Unit has adjustable air intake in the venturi tube, pilot valve adjustable from outside. Long, heavy cast iron draft stack insures proper draft and complete combustion.

Sizes	2"	3"	4"
Sh. wt.	450	480	500

Figure No. 236

Figure No. 450

"VAREC" *Approved* FLAME TRAP ASSEMBLY

Flame Trap and Thermal Shutoff Valve Unit self-contained, simple, foolproof. Installed in all gas lines supplying gas utilization equipment. No expensive fitting-up necessary. Arrests flame propagation. Easy inspection and maintenance Aluminum and stainless steel. Non-corrosive. Flame Trap Element listed by Underwriters' Laboratories for vent lines in oil tanks.

Sizes	2"	2½"	3"	4"	6"
Sh. wt.	90	100	115	150	200

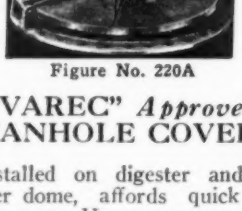


Figure No. 220A

"VAREC" *Approved* MANHOLE COVERS

Installed on digester and gas holder dome, affords quick and easy access. Has square, graphite-impregnated, fire proof gasket. Non-sparking. Gas-tight.

Sizes	18"	20"
Sh. wt.	100	110

Figure No. 51A

"VAREC" *Approved* FLAME CHECK

Acid resisting Union type fitting. Positive flame stop for small lines. Has five 40-mesh fire screens. Easy inspection and maintenance.

Sizes	½"	¾"	1"
Sh. wt.	10	10	10

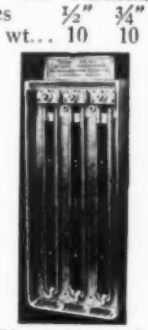


Figure No. 216A

"VAREC" *Approved* MANOMETERS

Single or Triple tube. Open or push-button control types. Accurate. Aluminum housing. Bronze fittings. Pyrex glass. Automatic—Fireproof — Safe. Sizes 6" to 36".

Sizes	9"	12"	15"
Sh. wt.	16	18	20

Figure No. 387

"VAREC" *Approved* SENSITIVE PRESSURE (REDUCING) REGULATOR SINGLE PORT

Maintains upstream or downstream pressure to within 0.5" of water of pre-determined pressure. Positive Shutoff. Aluminum body. Throttling type inner valve. 18-8 stainless steel trim. Sizes 2" to 6".

Sizes	2"	2½"	3"	4"
Sh. wt.	110	115	140	175

Figure No. 211A

"VAREC" *Approved* BACK PRESSURE (REDUCING) CHECK VALVE

Installed in relatively low pressure gas lines. Prevents back flow through meters. Non-shattering, non-pulsating, non-corrosive, non-sparking.

2"	3"	4"	6"
20	35	70	125

Figure No. 187

"VAREC" *Approved* SUPER SENSITIVE PRESSURE (REDUCING) REGULATOR DOUBLE PORT

Maintains upstream or downstream pressure to within 0.2" of water of pre-determined pressure. Standard working parts 18-8 stainless steel with synthetic rubber diaphragm. Non-corrosive. Sizes ½" to 10".

2"	2½"	3"	4"	6"
190	200	233	260	350

Figure Nos. 48 and 42A

"VAREC" *Approved* SAMPLING HATCH COVERS

For use on digester domes. Available in several combinations of materials. Non-corrosive, gas-tight, self-closing, spark-proof. Figure 42A Flanged and Figure 48 Screwed.

4"	6"	8"	10"
12	17	23	27

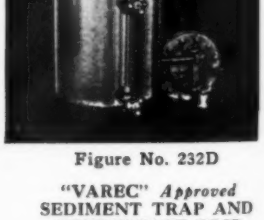


Figure No. 232D

"VAREC" *Approved* SEDIMENT TRAP AND CONDENSATE DRIP TRAP ASSEMBLY

Cast iron construction. 18-8 stainless steel working parts. Hand operated or automatic. Sizes 2"-2½"-3"-4".

THE VAPOR RECOVERY SYSTEMS COMPANY

COMPTON • CALIFORNIA • U.S.A. — Cable Address VAREC COMPTON (All Codes)
NEW YORK CITY — CHICAGO, ILL. — HOUSTON, TEX. — CLEVELAND, OHIO
Agencies Everywhere

Send for "Varec" Catalog S-3 for complete Sewage Gas Control Equipment.

"Varec" EQUIPMENT

GAS ENGINE MAINTENANCE AND OPERATION

By L. S. KRAUS
Chief Chemist, Peoria Sanitary District, Peoria, Ill.

IN 1935 the Peoria Sanitary District installed a gas engine-driven generator and a gas engine-driven blower in order to make effective use of the sewage sludge gas produced at the plant. The gas, a mixture of carbon dioxide and methane containing about 100 grains of hydrogen sulphide per 100 cubic feet, has a net calorific content of approximately 600 Btu. per cu. ft. The hydrogen sulphide is removed in iron oxide purifiers (gas scrubbers) to a concentration of less than 20 grains per 100 cu. ft. and the resulting gas is delivered to the engines at 5 inches of water pressure. Pressure is controlled at a relatively constant value by a 50,000 cu. ft. gas holder floating on the line.

The power plant consists of two engines, one of 300 hp. rating driving a 200 kw. generator, and the other a 535 hp. rating driving a Roots-Connersville blower discharging 12,600 cu. ft. per minute at 327 rpm.

The generator engine is a Worthington 5 cylinder unit of 12¼ inch bore and 14½ inch stroke rated at 300 hp. at 69½ lb. mep. and 400 rpm. It is equipped with separate force feed lubrication on the liners and two spark plugs per cylinder, each fired by a separate magneto. The air to the mixing valve is filtered through air mat filters. This unit operates at about 75 per cent load most of the time.

The blower engine is a Worthington 6 cylinder unit of 15 inch bore and 17½ inch stroke rated at 535 hp. at 69½ lb. mep. and 327 rpm. It is equipped the same as the generator engine with respect to features of lubrication, ignition and air filtering. This engine operates at practically full load torque and speed for a very large part of the time.

Each unit is equipped with pressure and temperature safety devices on both the oil and water system, and in addition is protected with automatic over-speed safety control. The engines are designed for continuous operation. The cylinders are of the replaceable liner type, equipped with positive force feed lubricators. In both engines the pistons, which are not oil cooled, are provided with four compression ring grooves, one drilled oil groove above the wrist pin, and one undrilled oil ring groove at the bottom of the piston skirt. The piston is undercut below the bottom ring groove. The sump for the engine oil circulating system is formed in the base of the engine crankcase. Oil is pumped by a gear pump directly connected to the crankshaft. Main and crankpin bearings are of the tin base babbitt type; wrist pin bearings are hardened steel pins operating in bronze bushings.

The installation has no standby equipment other than electrical equipment operated by power purchased from the local power utility. It is therefore necessary that the equipment operate for as much of the time as possible.

A program of maintenance has been adopted to reduce engine outage to a minimum and operate with safety regarding accidental shutdowns. These engines have been in operation over ten years. Rather complete data on their operation and maintenance have been kept and the following information represents averages over the ten-year period.

Maintenance Program

Routine engine overhauls are scheduled at six-month intervals of continuous operation, but occasionally excessive oil consumption or excessive blow-by has caused the overhaul to be undertaken before the six-month period has expired. Short shutdowns to change crankcase oil, repair water leaks, inspect newly installed bearings and replace an occasional faulty spark plug or valve are infrequent necessities.

The six-month overhaul includes the following: Cleaning pistons and rings; measuring piston and liner diameter; measuring piston ring dimensions and replacing rings when necessary; determining and adjusting main and crank pin bearing clearances; measuring wrist pin bearing clearances (yearly); inspecting exhaust and intake valves and replacing when necessary; inspecting and resetting gaps of spark plugs; inspecting cam shaft gears and other drive gears; cleaning cam followers and follower guides; inspecting and replacing worn governor parts; checking magnetos and replacing one magneto with spare; checking safety devices; cleaning oil cooler when necessary; cleaning oil lines when necessary; cleaning oil pumps when necessary.

Lubricating Oil

The first important operating problem encountered was in the selection of a proper lubricating oil for the circulating system. The engine manufacturer's specifications on oil were quite broad and the oil supplier recommended an extra heavy turbine oil for use in the circulating system and on the liners. It soon developed that the viscosity of the oil used was increasing with great rapidity; in one instance from 625 sec. S.U. at 100° F. to 1400 sec. S.U. at 100° F. in 30 days of use. The reason for the increase was not clearly ascertained, some persons holding that the oil was not a "straight run" oil but a mixture of a very low and a very high viscosity oil and that the low viscosity oil vaporized. Others believed that rust and other metallic oxides in the newly erected system acted as catalysts to cause polymerization of some of the hydrocarbons present in the oil.

After experimenting with turbine oils of various viscosities it was found that a heavy grade "straight run" oil was satisfactory. The viscosity of the oil increased slightly, but remained practically constant after about two weeks of operation.

Due to ring sticking problems on the fully loaded blower engine a so-called "detergent" type of oil was found to be of benefit for the force feed lubrication of the liner.

The oil used in the liner lubricator of the generator engine is the same as that used in the sump circulating system.

The lubricating oil purification system originally consisted of batch centrifuging. The oil in the engine sump was allowed to increase to about 0.75 per cent solids insoluble in petroleum ether. The batch was dumped and centrifuged to a minimum solids content of approximately 0.15 per cent. The batch was again reused and the cycle repeated until the neutralization number increased to about 1.0 milligram KOH per gram. The oil was then discarded.

The oil purification system was then changed to that of continuous centrifuging on the larger engine, which runs continuously at practically rated full load torque. The amount of makeup oil required by this engine was added as new oil to the sump of the smaller engine, which required practically no sump additions, and an equal amount was withdrawn and added to the sump of the larger engine. The turnover in the sump of the smaller engine was about a 10-day period. This operation kept the oil in both engines in as good condition as the centrifuge could provide and eliminated the need for shutting down either engine for changing the oil.

During the period of using this system a batch purifier employing bentonite as an adsorbent and a continuous bypass filter

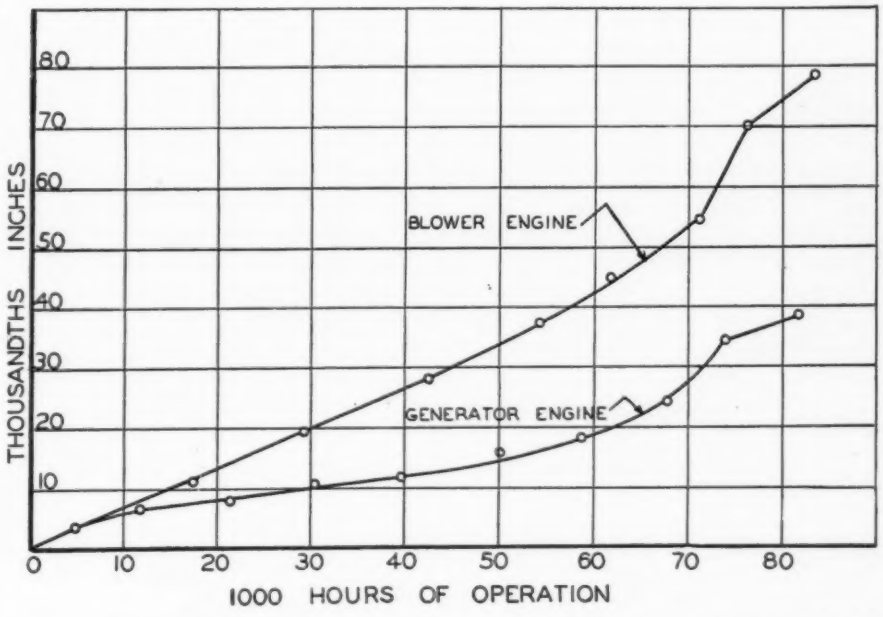


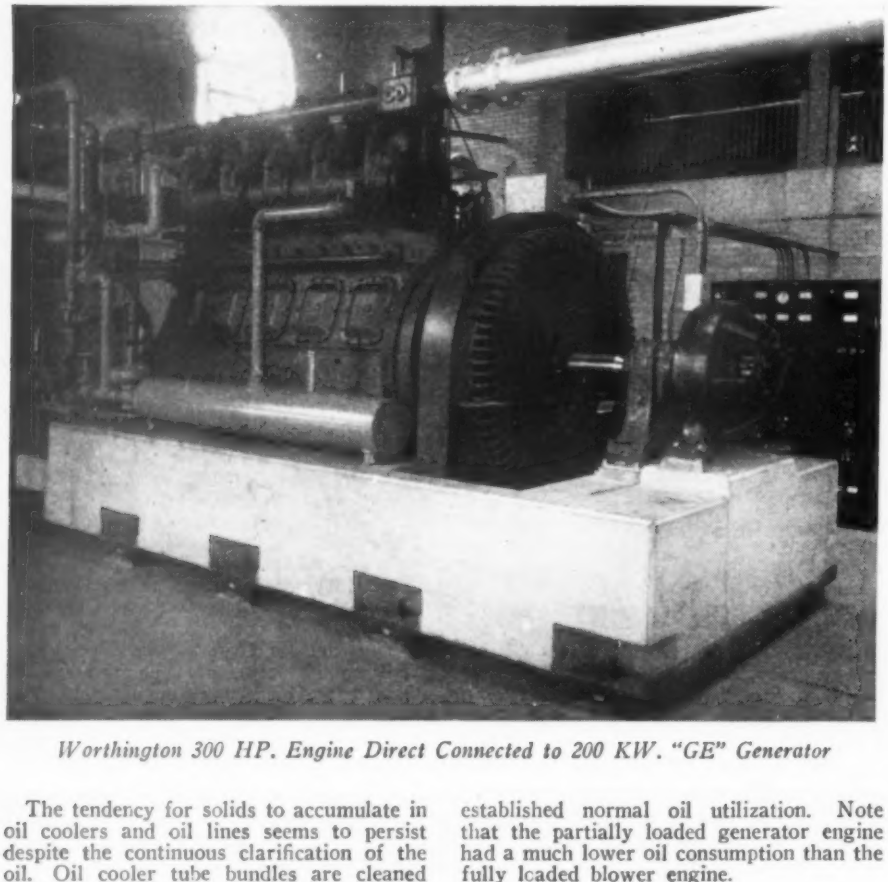
Fig. 1. Increase in Liner Diameter for Both Engines During 10 Year Operation Period

using a prepared Fullers earth as an absorbent were tested. Each of these was found to have certain disadvantages for our particular situation and a cotton waste type of continuous bypass filter was tested and finally installed on each engine. In addition to this, the centrifuge operated on continuous bypass operation for the purpose of removing small amounts of water present in the oil due to blowby.

This system of oil purification is in use at the present time. It is the practice to dump the oil batch after about 2,500 hours of engine operation. This is done to eliminate the tendency of the oil to deposit a varnish-like compound on the engine surfaces. It is our observation that if a batch of oil is retained in the system for too long a time the varnish effect will be encountered. This effect was first observed during the tests of the adsorptive type of oil purifiers.

Year	Rated BHPH per gal. Generator Engine	Blower Engine
1937	5040	3840
1938	7080	4630
1939	5620	3020
1940	4190	2340
1941	4230	3170
1942	4830	3870
1943	4480	4180
1944	3470	3590
1945	3330	4670

The engine manufacturer guaranteed 3000 rated BHPH per gal. at the time of purchasing the equipment. It will be noted that the generator engine was consistently above that value and that with the exception of one year the blower engine was above the guarantee. The blower engine, running continuously at rated full load torque experienced a sharp increase in oil consumption as the wear of the liners increased. In 1941 a change in oil control ring design corrected the difficulty and re-



Worthington 300 HP. Engine Direct Connected to 200 KW. "GE" Generator

The tendency for solids to accumulate in oil coolers and oil lines seems to persist despite the continuous clarification of the oil. Oil cooler tube bundles are cleaned periodically when the temperature differential between the influent and effluent oil is decreased so that the oil to the lubrication system is above 140° F. This is accomplished by boiling the tube bundle in a trisodium phosphate solution and then blowing the space between the tubes with air carrying kerosene. The cleaning of oil lines is done periodically, but an annual inspection of these lines is considered necessary.

At the present time a detergent type of oil is being used for both the bearing and liner lubrication on the blower engine. The efficacy of this material for lubrication of this engine has not yet been determined.

Oil consumption is to a large degree a matter of piston and piston ring design and piston ring cleanliness. It is also effected by engine speed and cylinder mean effective pressures. Oil consumption data on the two engines is as follows:

established normal oil utilization. Note that the partially loaded generator engine had a much lower oil consumption than the fully loaded blower engine.

Piston Rings

The choice of piston rings is an important factor in maintaining continuity of operation and reasonable rates of liner wear and oil consumption. The purposes of the rings are three-fold:

First, to provide an automatically adjustable bearing surface against the liners so that the gases in the combustion zone will be sealed in the space between the head and the piston and not blow by the clearance between the piston and the liners. Toward this end, four piston rings are provided in the piston area above the wrist pin on these engines. These are either angle cut rings with about a 1/16 inch gap or step seal rings with the gas so designed as to provide an overlapping joint which affords a measure of sealing at this point. In some cases it is desirable to use a two-piece ring which is designed to eliminate the ring gap. In addition these rings may be provided with means for rapidly conforming to the irregularities in the liners, such as rings provided with a tapered face, or soft metal inserted rings which project several thousandths of an inch beyond the ring face, or rings plated with tin. All of these provide a high rate of wear in the initial run-in period and permit rapid ring seating.

Second, to provide as much heat transfer from the piston to the water-cooled liner as possible. In order that this heat transfer be effective, the ring must be free in the groove and must afford a reasonable contact area to the oil film on the liner. As far as we are able to determine, the matter of heat transfer is not a sufficiently important factor to cause ring designers to go to special rings to better accomplish this end. It is most important, however, that the rings remain free in the grooves, otherwise the loss of heat from the piston will be impeded and the resulting higher piston temperature will cause additional ring sticking due to oil carbonization.

Third, to afford a means of preventing oil which is thrown against the liner by the bearing lubrication splash from entering the compression ring zone in excessive amounts. To accomplish this, these engines are provided with two oil control rings, one above the wrist pin and one near the bottom of the piston skirt. The ring groove above the wrist is provided with drain holes to the back of the piston and the ring used in this groove may be of the slotted type with one or two bearing surfaces, or the single bearing surface ring with milled sections in the bottom which afford oil passage. The principle behind the design of oil control rings is to obtain the proper pressure against the oil film on the liner with a relatively sharp scraping surface without completely removing the oil film. The more of such surfaces provided the more effective will be the oil removal. Bearing pressure is controlled by providing small bearing areas, and in some cases by increasing ring tension with springs installed in back of the ring.

No particular difficulty due to ring sticking, excessive oil consumption or blow-by was encountered on the 12¼x14½ in. partially loaded generator engine; however, the 15x17½ in. fully loaded blower engine presented considerable trouble in each of these phases of ring application. It is now considered that these troubles were due to a combination of choice of oil, choice of ring type and increasing difficulties brought on by liner and piston wear. Attempts to correct the difficulties by experimenting with different types of rings have led to the following conclusions:

1. Step seal compression rings are more satisfactory than angle cut compression rings.
2. Two-piece compression rings are very satisfactory in the third and fourth groove.
3. Bronze inserted compression rings are not desirable in this particular installation.
4. Tapered face compression rings are of some value in causing rapid conforming of the ring to the liner.
5. Single or double bearing surface slotted oil control rings are very satisfactory in the oil ring groove above the wrist pin. The double surface ring gives more effective oil removal.
6. Oil control rings with milled bottom areas are not satisfactory in the oil ring groove above the wrist pin.
7. Single surface oil control rings are satisfactory in the ring groove at the bottom of the piston skirt.

8. Spring reinforcements in back of oil control rings are unsatisfactory due to spring failure.

At the present time the use of step seal rings in the compression ring grooves, a double surface slotted oil ring in the drilled oil groove above the wrist pin, and a beveled and grooved oil ring as a bottom oil control ring is considered a satisfactory combination. Oil control is very good, although none of the ring combinations tried have corrected a condition of abnormal blow-by. It is our opinion that, given a reasonable condition of oil consumption, ring sticking is largely a matter of the use of a proper oil for liner lubrication, provided that ring clearances are adequate.

When rings are installed in a piston it is well to chamfer the edges to reduce the tendency to slough off metal particles. Rings should be measured at several places for radial thickness before installation and again at each overhaul. Experience indicates that 15 in. diameter rings may be reused until the radial thickness decreases about 0.020 in. It is desirable to return each ring to the same piston ring groove from which it was taken, and also to change as few rings as possible. With this rule for discarding rings, we have never observed a piston ring that failed due to loss of tension alone. It appears that loss of tension is due to overheating, and this should not occur in a properly lubricated engine.

Piston ring life on the generator engine is in the order of 24 months while on the blower engine it is about 17 months.

Liners

Liner wear is closely allied with piston ring operation. In order for liner wear to be a minimum, rings must be free and a minimum of carbon and metal particles must be present. This condition can be brought about by the selection of proper piston rings and lubricating oil, providing reasonable mean effective pressures are maintained. High rates of liner wear are observed during periods of extensive ring sticking. During the period of the use of bronze inserted rings a very high rate of liner wear was observed.

Measurements of liner wear were determined by measuring liner diameters at three points in the liner: The point opposite the second ring groove when the piston is at upper dead center, the center line of the wrist pin when the piston is at upper dead center, and between No. 4 (compression ring) and No. 5 (oil ring) when the piston is at lower dead center. Thus the upper measurement is taken in the zone of greatest wear where the No. 1 compression ring bears on the liner under high temperature and poor lubrication. The lower measurement is taken in the zone of good lubrication where only the two oil rings bear against the liner.

Fig. 1 indicates the maximum rate of increase in liner diameter for both engines during the ten-year period. The data for these curves are shown in Table I. It is noteworthy that the rate of liner wear on the generator engine has been low. The value for 81,736 hours of operation of the maximum rate of increase in liner diameter as determined at the upper transverse dimension is 0.00048 inch per 1,000 hours of generator engine operation. This engine has operated largely at three-fourths load and piston rings have been continuously free in the grooves. In addition blow-by has not been a problem.

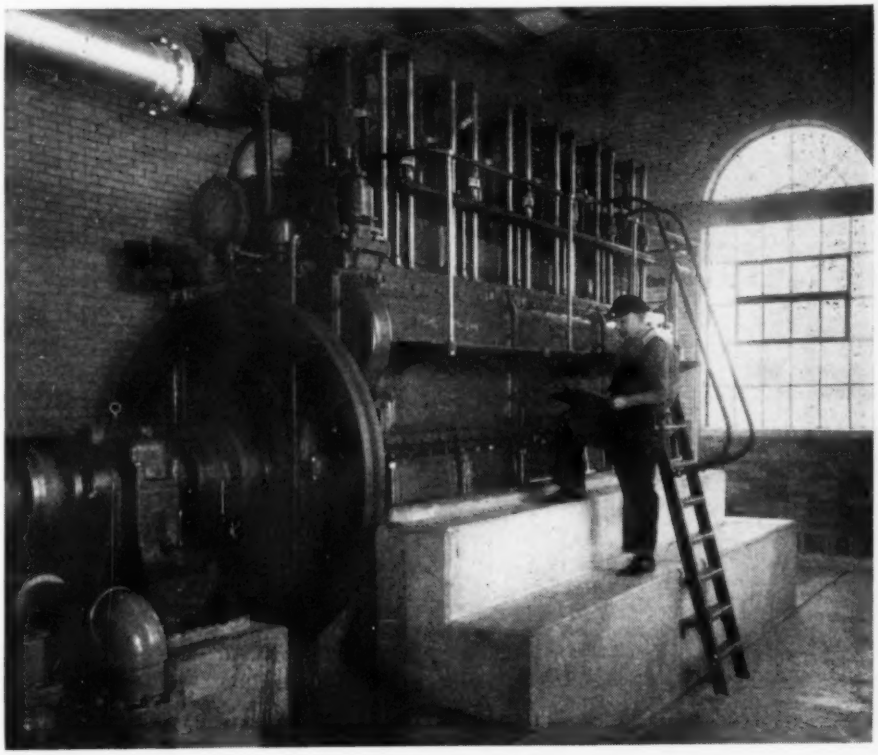
The rate of liner wear on the blower engine has been considerably higher than on the generator engine. The maximum

TABLE I
Maximum Increase in Liner Diameters

Generator Engine		Blower Engine	
Hours of Engine Operation	Maximum Increase (Inches)	Hours of Engine Operation	Maximum Increase (Inches)
4,775	0.004	4,886	0.005
11,519	0.007	11,705	0.009
21,265	0.008	17,409	0.011
30,928	0.011	29,284	0.019
39,551	0.012	42,562	0.028
50,033	0.016	54,225	0.037
58,640	0.018	62,837	0.045
67,591	0.024	71,202	0.055
74,131	0.035	76,323	0.070
81,736	0.039	83,691	0.078

rate of increase in liner diameter for the 83,691 hours of engine operation at the upper transverse dimension is 0.00093 inch per 1,000 hours, or about twice the rate of wear as that of the generator engine. This is in part due to the fact that this engine is always operating near maximum rated mean effective pressure and for long periods at maximum rated speed. It is also due to inability to properly solve the problem of oil control, ring sticking and blow-by. Experiments with equipment needed for operation are necessarily slow and inconclusive, particularly where more than one variable is apt to be changed during a given test period. High rates of wear are noted during periods of ring sticking and usually following the installation of a set of new rings. It appears that the rate of liner wear tends to increase somewhat as a liner becomes more worn. This is probably due to the increase in rate of blow-by which accentuates the difficulty of proper lubrication.

As liner and piston wear increases the tendency for the piston to slap becomes more pronounced. The slap is apparently caused by excessive clearance between the liner and the piston and is evidenced by a reversal of the piston thrust from one side of the liner to the other, producing a sharp noise, and in bad cases a sufficient blow against the side of the liner to endanger the lubricator connections to the liner. It is rumored in the engine field that liner replacement is not necessary until liner wear is of the order of 0.010 inch per inch of piston diameter. At Peoria it was necessary to replace the liners of the blower engine when the maximum wear was about 0.005 inch per inch of liner diameter.



Worthington 535 HP. Engine Direct Connected to Roots-Connersville 12,600 cfm. Blower

Bearings

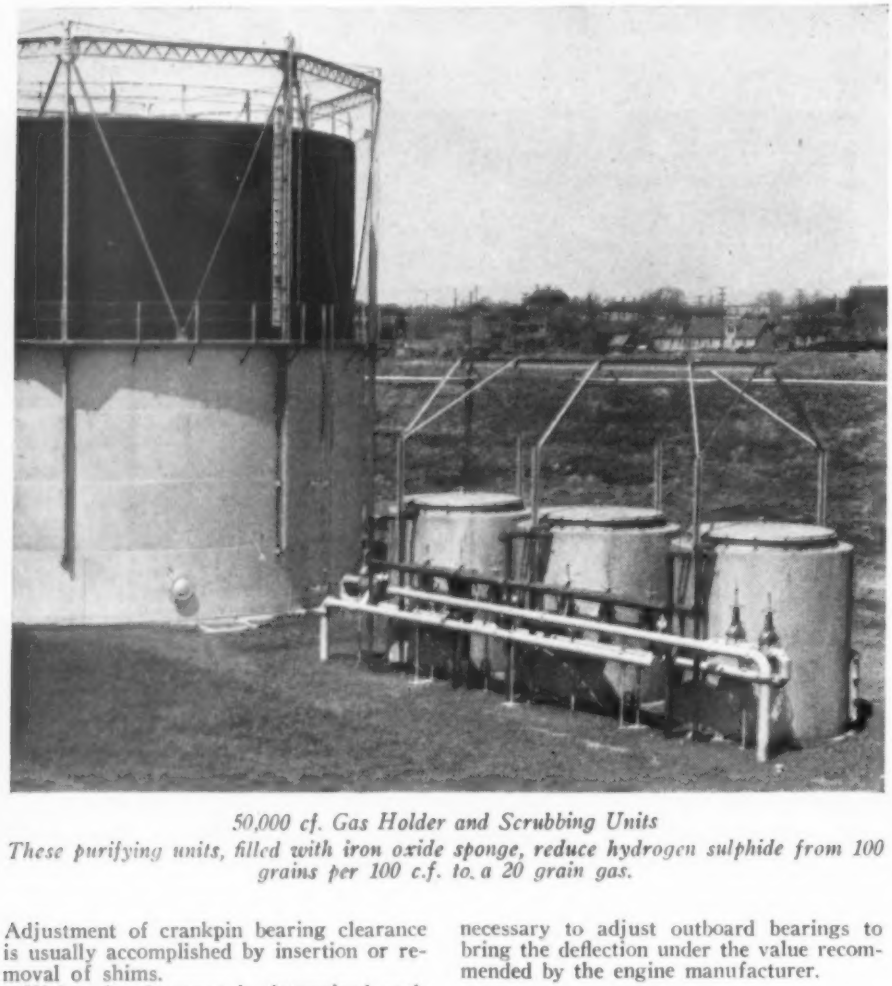
At each six-month overhaul the main and crank pin bearings are inspected and the clearance determined. The clearance on the main bearings is determined by the lead or fuse wire method. The main bearing cap is removed and fuse wire of 0.010 inch diameter is placed circumferentially on the journal at two, three or four points, depending on the bearing length. The cap is replaced and the bolts drawn tight. The cap is then removed and the compressed wire is measured with a micrometer caliper. The thickness of the wire is approximately the bearing clearance. Care must be taken to replace the bearing cap so that it is exactly centered on the journal. To accomplish this guide shims are inserted between the cap and the recess in the frame in which the cap sets. If necessary, the clearance is adjusted either by scraping the cap or removing shims from under the cap. It is imperative that the clearance be redetermined following each adjustment.

Shims should be inspected after installation to make certain that the clearance between the shim and the journal is not excessive. Large gaps at this point permit the loss of much oil and reduce the oil pressure to the crankpin bearings and wrist pins.

When tightening main bearing cap nuts, care should be taken to tighten them gradually so that uniform pressure may be exerted over the cap casting.

Where shell inserted main bearing caps are used, the shell must not project beyond the face of the cap flanges.

The crankpin bearing clearance is determined by the insertion of feeler gages through the full length of the bearing.



50,000 cf. Gas Holder and Scrubbing Units
These purifying units, filled with iron oxide sponge, reduce hydrogen sulphide from 100 grains per 100 c.f. to a 20 grain gas.

Adjustment of crankpin bearing clearance is usually accomplished by insertion or removal of shims.

Wrist pin clearance is determined each year by removing the pin from the piston and inserting feeler gages through the full length of the bushing. Determining wrist pin clearance by measuring pin and bushing diameters by the micrometer caliper is entirely unsatisfactory and must not be used. Wrist pin clearance is re-established by grinding the pin to a highly polished surface and installing a new wrist pin bushing in the eye of the connecting rod. The bushing is prepared to exact outside diameter and approximate inside diameter and is cooled in dry ice and inserted in the eye of the connecting rod. After it reaches room temperature it is reamed or scraped to provide the proper clearance and uniform bearing over its entire area.

In general few bearing difficulties have been experienced on these engines. Bearing troubles have come about due to checking and melting of the babbitt and have been confined to such small areas of the bearing that they have not caused the crankshaft to be unsupported. Where checked sections have come loose the bearings were replaced only if the loose section was near either end or adjacent to the oil groove. Otherwise the bearing is kept in service. Small melted areas have been repaired by filling with molten babbitt and relieving this section by scraping so that it does not bear on the journal. Most of the bearings replaced were main bearing caps. In no instance was the crankshaft journal scored by bearing troubles.

Crankshaft deflection as indicated by a sensitive indicator supported between the crank webs is determined before and after each overhaul. Thus far it has been unnecessary to adjust engine main bearings to reduce crankshaft deflection. It has been necessary to adjust outboard bearings to bring the deflection under the value recommended by the engine manufacturer.

Intake and Exhaust Valves

Intake and exhaust valve problems have been minor but persistent. When the engines were purchased they were equipped with cast iron valve cages and valves of cold rolled steel stems with cast iron heads. These valves gave and are still giving excellent service as intake valves but were not entirely satisfactory as exhaust valves. In the latter service the valve head seats wore and pitted excessively, thus reducing the valve life, and the cold rolled stem corroded and eroded considerably just above the valve head where it was exposed to the hot exhaust gases at high velocity. In addition valve cage guides and seats wore considerably.

These difficulties were somewhat corrected by using valves of austinetic steel heads and stainless steel stems. Cages were modified to take guide bushings of nitrited cast iron and manganese bronze, and replaceable cast iron seats were installed. These changes provided much better operation but did not eliminate exhaust valve troubles. At the present time corrosion of valve stems and rapid wear of valve seats are largely eliminated; however, the stainless steel valve stems are found to warp unduly and valve stem and valve stem guide wear is a problem. This does not take place in all of the exhaust valves but it does necessitate occasional shutdowns to install a spare valve. Attempts to correct this situation have been made without success. The cages have been provided with fittings for lubrication of the stems, but this has not remedied the condition. It has been observed that a certain amount of warping takes place in the valve cage, and it may be necessary to prevent this before a satisfactory solution to valve warping and valve guide wear can be found.

Valve maintenance resolves itself largely into reconditioning the seats in the valve and in the cage. This is done by grinding the valve against the seat with abrasives when the wear and pitting is slight. When this method cannot be employed, the valve and seat are ground separately in a lathe with an accurate high speed carborundum wheel and then finally lapped against each other with a grinding compound. Valve seats are tested with prussian blue paste before placing them in service.

To correct for cage warping the seat is checked against the valve stem guide. If the seat plane is not perpendicular to the guide axis, it is made so by grinding. Since exhaust valves are water-cooled, occasional inspection of the water jacket for scale deposits is desirable. When these deposits are appreciable the valve cage jacket is filled with muriatic acid, which dissolves the scale. Where frequent treatment is necessary, corrosion inhibitors must be added to the muriatic acid. A clean water jacket insures lower valve operating temperature and reduces a difficult maintenance problem.

The care of intake and exhaust valves cannot be overemphasized. In order that engine operation be efficient, these valves must be in practically perfect condition. Fuel economy and ability to carry load are closely related to valve operation and effective valve seating. Valve operating mechanisms are checked at each overhaul. Cam followers are kept free in the guides, rocker arm mechanism bearings are inspected and replaced when necessary, and clearance between the valve stem and lever arm are maintained at the proper value. Valve stem clearance is checked at least every 100 hours of engine operation. A mixture of light oil and kerosene is applied to the top of the valve stems three times each day.

Ignition System

The ignition system used on these engines consists of two magnetos firing two spark plugs in each cylinder. High tension distribution is employed.

Magnetos are of the rotating magnet-stationary coil type and are equipped with impulse couplings which provide high voltages during low speed starting. Magneto maintenance is scheduled for replacement of one magneto each six months. Thus each magneto is in operation for one year before overhaul. Maintenance consists in cleaning the unit and replacing fixed and rotating high tension electrodes when necessary. The gap for these electrodes is adjusted to approximately 0.010 inch. Low tension breaker points are adjusted each year and replaced when necessary. Bearing replacement is occasionally required.

Spark plug problems on these engines were largely solved by the use of a plug developed for this purpose by the Cham-

pion Spark Plug Co. The plugs now in use have an average life of about 11,500 operating hours and do not require gap adjustments more frequently than every 2,000 operating hours. When removed from the engine, spark plugs are adjusted to 0.015 inch gap. It is considered satisfactory to allow the gap to increase to 0.040 inch before regapping.

Wire employed for conducting the high voltage current from the magneto to the spark plug is stainless steel heavily insulated wire with treatment to prevent insulation deterioration due to oil.

Fuel System

The fuel system consists of a gas pressure regulator, gas-air mixing valve, and governor. Little difficulty has been experienced in any of these units with the possible exception of the governor. Both the pressure regulator and gas-air mixing valve should be cleaned and adjusted yearly. The governor should be inspected at each overhaul.

Governor difficulties in the early period of operation were brought about by inadequate lubrication and by corrosion due to crankcase vapors passing into the governor housing. By changing the governor lubrication from the force feed lubricator to the oil circulating system, thus greatly increasing the feed to the unit, and by preventing the crankcase vapors from entering the governor housing, the problem was completely solved. At present governor maintenance is slight. Thrust collar bearing surfaces are covered with stellite in order to reduce the rate of wear and thus reduce frequency of replacing this part.

Lubrication System

The lubrication system maintenance has been largely a matter of cleaning. The oil circulating pump, force feed lubricator and oil lines both inside and outside the engine are inspected yearly and cleaned when this is considered necessary. Check valves on liner lubricator lines are cleaned at each overhaul. The cleaning of the oil cooler has been described under the section on lubricating oil. The linkage mechanism for driving the force feed lubricator should be checked and repaired when necessary.

Water Circulating System

The water circulating system on these engines consists of an electrically operated centrifugal pump which discharges the water through cooling piping and thence to the engine water jackets. Since the cooling system is not of the evaporative type, the tendency for scale formation is greatly reduced. The water used for makeup is partially softened by cold lime-soda treatment. Some scale does form on the water jackets, particularly on the upper few inches of the liner and in the exhaust manifold. These deposits, which attain a depth of about ⅛ inch, are removed every two years by mechanical means or treatment with muriatic acid.

Air Starting System

The air starting system consists of a two-stage air compressor, air tanks, air starting valves operated by camshaft-controlled push rods and air starting check valves.

Difficulties with these units have been minor. The air tanks are provided with a separator for removing water continuously and in addition a blow-off valve is installed in the air line to the engine for removing any water accumulation in the piping and tanks not taken care of by the separator. The system is blown off for a short time before starting the engines.

The sealing of air starting valves and check valves must be maintained by occasional grinding of the valves against the valve seats, and the seal between the check valve and the head must be perfect in order to prevent exhaust gas from passing through these valves during normal engine operation. If the exhaust gas is allowed to flow through the air starting system, the valves will become corroded and will not be fit for use when needed. Air starting check valve springs must provide sufficient tension to prevent the valve from opening on the intake stroke.

Operation

In general, engine operation has been most satisfactory. The engines are under constant surveillance of an operator. Hourly readings of water, oil and exhaust gas temperatures, together with readings of gas consumption and load, keep the operator aware of the condition of the engines and results in very few automatic shutdowns due to improper operation. Thus engine operation from the standpoint of operator's duties is largely that of inspection and lubrication with occasional need for making adjustments to insure operating continuity.

TABLE II

Summary of Engine Operation

	Blower Engine	Generator Engine
Total hours of engine operation	83,353	83,669
Total days since starting operation	3,652	3,652
Average hours operation per day	22.8	22.9
Oil consumption rated BHPH per gallon	3,550	4,480
Speed—% of rated maximum speed	90.9	.....
M.E.P.—% of rated M.E.P.	97.0	68.5
Fuel consumption—BTU/BHPH	9,650	.....
Fuel consumption BTU/Delivered KWH	.....	16,200

Table II is a summary of operating characteristics for both units; values are averages of daily data for the ten-year period.

Engine outage was largely due to shutdowns for maintenance; however, some of the outage was caused by Illinois River floods and lack of gas. The outage due to routine overhauls is approximately eight days per year for the blower engine and six days per year for the generator engine.

The average values for lubricating oil consumption do not include batches dumped but indicate oil burned in the engine.

The fuel consumption is an estimate based on accurately measured gas volumes and on Btu. values computed from analyses of grab samples of gas collected once monthly. In the case of the blower engine the bhp. used was based on tests made when the blower was installed. The output of the generator is accurately metered.

Cost of Power

Table III indicates the net saving in operating cost to the Sanitary District over the ten-year period of operation.

The power produced was computed by adding the KWH. generated as electrical energy to the computed amount of power which would be required to drive a motor-driven blower of the same type as the gas engine-driven blower. The latter quantity of power generated is a purely hypothetical value since the motor-operated blower would not have the flexibility of speed control at high efficiency normal to a gas engine-driven unit.

Note that the power generated is about 97 per cent of the total power used and that the net saving to the Sanitary District in annual operating cost is over $36,000.

In order to compute the actual cost of power consumed it was assumed that the capital investment would be written off in 20 years and that the interest rate would be 4 per cent. The cost of power purchased is very high due to the KVA. demand charge in the power contract. The cost of about 3 per cent of the total power produced exceeds the cost of operation required to produce the remaining 97 per cent.

The cost of power used, 4.2 mills per KWH., is greater than the actual cost to the Sanitary District due to PWA assistance in the cost of the initial installation. This factor reduces the cost of power used by the District to about 3.7 mills per KWH. The cost of power produced is about 2.6 mills per KWH.

TABLE III

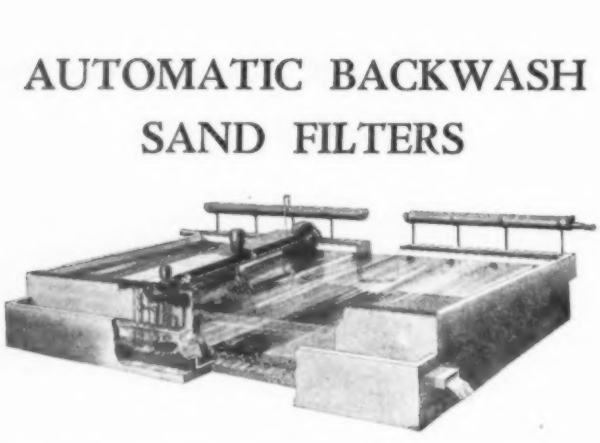
Gas Engine Cost Data

Years of operation		10.0
Power produced		42,900,000 KWH
Power purchased		1,700,000 KWH
Power consumed		44,600,000 KWH
Cost of power if all were purchased		$468,300
Actual cost of power		55,724
Gross saving in power cost		$412,576
Cost of engine operation:		
Maintenance	$ 17,023	
Supplies	13,652	
Labor	20,480	
Total		$ 51,155
Net saving		$361,421
Total cost of gas engine installation	$106,855	
Cost of improvements	3,293	
Total capital cost		$110,148
Annual debt service on basis of 20 years and 4% interest		$ 7,820
Net cost of power:		
Cost of operation	$ 51,155	
Debt service	78,200	
Power purchased	55,724	
		$185.079
Net cost per KWH used		0.0042

HARDINGE
COMPANY INCORPORATED

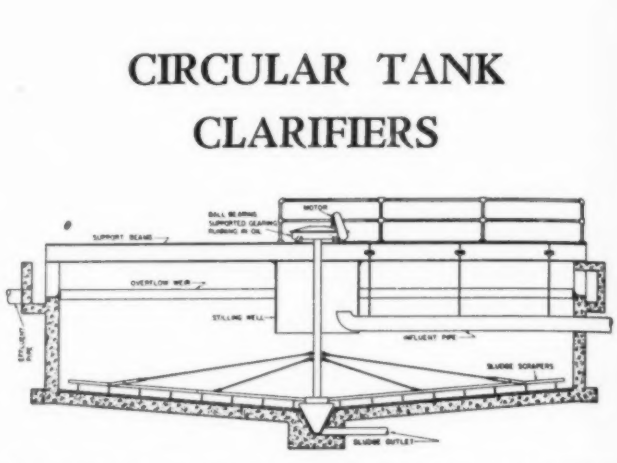
YORK, PENNSYLVANIA — 240 Arch St. • Main Office and Works
NEW YORK 17—122 E. 42nd St. • 205 W. Wacker Drive—CHICAGO 6
SAN FRANCISCO 5—94 Natoma St. • 200 Bay St.—TORONTO 1

AUTOMATIC BACKWASH SAND FILTERS



Here is the sanitary engineer's dream come true! . . . a sand filter which *cleans itself,* automatically, with no interruption whatever to the filtering operation. No shut-down or change-over is necessary while cleaning is in progress. The secret of this remarkable Hardinge filter lies in its compartmented filter bed and traveling backwash mechanism, which automatically cleans and removes the accumulated solids from one compartment at a time—on a predetermined time cycle or with increase in head pressure. It is extremely efficient on pre-settled sewage, removing 75% to 80% of the suspended solids—90% or better if chemicals are added. On an industrial water supply, an effluent running less than 1.0 p.p.m. is continuously delivered.

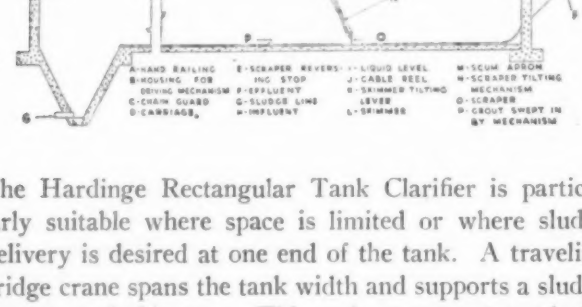
CIRCULAR TANK CLARIFIERS



In the Hardinge Circular Tank Clarifier, double-spiral or cut-flight scrapers move the settled solids from periphery to tank center. The rotating sludge scraper is supported and operated from two beams which span the tank top. Driving mechanism is entirely enclosed in a waterproof housing. The Clarifier is supplied complete with motor drive unit, drive gearing in a weather-proof gear housing, walkway, railing from tank side to center, and influent well.

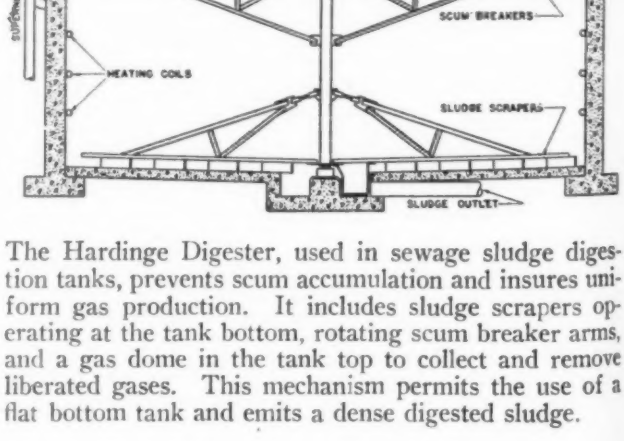
On Clarifiers over 55 feet in diameter, the rotating sludge scrapers are carried on top of a center stationary steel column which is connected to the tank side by a bridge.

RECTANGULAR TANK CLARIFIERS



The Hardinge Rectangular Tank Clarifier is particularly suitable where space is limited or where sludge delivery is desired at one end of the tank. A traveling bridge crane spans the tank width and supports a sludge scraper and skimmer. This unit moves automatically along the tank, scraping all settled solids into sludge hoppers at one end and discharging scum into a scum trough.

DIGESTERS



The Hardinge Digester, used in sewage sludge digestion tanks, prevents scum accumulation and insures uniform gas production. It includes sludge scrapers operating at the tank bottom, rotating scum breaker arms, and a gas dome in the tank top to collect and remove liberated gases. This mechanism permits the use of a flat bottom tank and emits a dense digested sludge.

THE SCUM PROBLEM FROM THE OPERATORS' STANDPOINT

By JOSEPH DOMAN
Sanitary Engr., Dept. of Public Works, Greenwich, Conn.

PART of the job of operators of separate sludge digestion systems is to secure proper digestion of solids in units already designed and constructed. No matter how similar the digestion units, each plant has its own individual patterns of behavior which must become known if satisfactory operation is to be secured. With reference to the scum problem, however, whatever differences there may be in behavior between individual plants, they are only differences in details, as the scum problem is essentially of the same general pattern for all separate sludge digestion plants. It is the purpose of this brief discussion to present this general pattern along with some important details pertaining to plant operation.

Essentials of the Scum Problem

As seen by the operator, the scum problem is essentially this: How can favorable digesting conditions be maintained in the scum layer in his own particular digestors? Regardless of the number, type and per capita capacity of digestors, the operator must aim at four objectives in order to solve this problem: (1) He must keep the scum layer properly thin and wet; (2) he must keep the scum solids well impregnated with digesting organisms; (3) he must maintain satisfactory digesting temperatures in the scum layer as well as in the rest of the digestor; and (4) he must maintain proper alkalinity in the scum as well as in the rest of the digestor. With digestors of insufficient capacity it will be much more difficult to achieve these objectives than with digestors of ample size, but if these objectives are aimed at, the operator can often improve the functioning of even overloaded digestors.

Keeping the Scum Layer Properly Thin and Wet

Unless the scum layer is kept sufficiently thin and wet, it will become so thick and compact as to prevent proper impregnation with digesting organisms; it will not be maintained at proper temperature; and it will probably develop an acid reaction, all of which are highly unfavorable for proper digestion. The importance of keeping the scum thin and wet is, therefore, very apparent.

Many digestors are equipped with either rectangular or circular mechanisms which slowly scrape or plow the scum from one part of the tank to another and then down into the supernatant below. The mechanisms are supposed to be operated a sufficient length of time every day to keep the scum well broken up and thus keep the scum thickness down to but a few inches.

Some digestors are now equipped with horizontal propellers on a motor-driven vertical shaft to keep the entire digestor contents either continually or periodically agitated.

Digestors with scraping or propelling mechanism are usually of the fixed roof type in which some of the digestor contents flow out of the tank when the raw sludge is being pumped in. The pumping of raw sludge provides more or less agitation in the digestor; hence the digestor effluent often contains an undesirably high amount of sludge solids. For this reason tanks equipped with such mechanism find their best application as primary digestors in two-stage digestion systems in which a secondary digestor, often of the floating cover type and without inside mechanism, is provided to render a better clarified supernatant as drawn from the tank and to further the completion of the digestion process. Excellent scum control is sometimes achieved by digestors equipped with mechanical scrapers or propellers, but sometimes the character of the sludge and method of operation are such that results are quite disappointing.

Some digestors are equipped with stationary perforated pipes or revolving jets directly in the scum layer, supernatant being pumped through them at times to keep the scum wet and agitated. Stationary perforated pipes have usually been unsatisfactory and the scum may become sufficiently compacted to render revolving jets also ineffective.

In digestors of the submerged roof, floating cover type, the most effective means of keeping the scum thin and wet is to pump relatively large quantities of supernatant liquor at low discharge pressure onto the top of the scum, the discharge point usually being several feet above the scum in the central collecting dome. Sometimes it is also advantageous to pump the supernatant into inspection manholes between the center dome and outside edge of the cover. Low pressure discharge is preferred to high pressure jetting because thoroughly wetting the scum has been found more effective than jetting, which develops short-circuiting channels through the scum into the supernatant.

The low pressure discharge also releases gas from the pumped supernatant so that with prolonged pumping the entire digestor contents become sufficiently degassed below the saturation point to reabsorb gas from the underside of the scum layer and permit the degassed solids to settle out. A proper flushing program of this sort will usually keep the scum sufficiently thin and wet to allow the establishment of favorable conditions for digestion. In developing such a program it is advisable to time the flushing after overnight settling or at least two hours after pumping raw sludge into the digestor in order to avoid introducing an excessive amount of raw solids into the scum along with the pumped supernatant.

In some cases the addition of ammonium sulphate has been reported as effective in dispersing and digesting scum while in other cases results have been reported as disappointing. This process is covered by patents and should not be employed without proper permission. Competent technical supervision is also required.

While many operators have succeeded in keeping the scum properly thin and wet, the foregoing considerations make it quite clear that considerable difficulty is encountered at many plants and each operator has to work out the best method for his own particular plant. It must also be borne in mind that some of the floating materials are of such character that they will not digest at all in spite of satisfactory temperatures, seeding and alkalinity. If allowed to accumulate, these materials may build up a troublesome layer of either oily or compacting material, thereby causing considerable impairment of digestor efficiency. These undigestible materials must be physically removed from the digestor either by pumping, scraping to a collecting well, scooping, or otherwise.

Keeping Scum Solids Impregnated With Digesting Organisms

When any of the above methods are effective in keeping the scum thin and wet, the intimate contact provided with the supernatant will usually provide sufficient impregnation with digesting organisms. Sometimes, however, it is advisable to reinforce the supernatant with digesting organisms by recirculating sludge from the bottom of the digestor into the supernatant. This type of sludge recirculation is regarded as preferable for this purpose to discharging sludge onto the scum as in the latter case some of the sludge solids may become entrapped in the scum and build up its thickness.

Maintaining Satisfactory Temperatures In the Scum Layer

Some of the floating solids, such as vegetable oils and greases, will digest only at relatively high temperatures. Although satisfactory digestion may take place at an average temperature of around 85° F., some of the digestible oils and greases require temperatures of at least 95° F. In boilers burning sludge gas there may be times, particularly in the winter, when sufficient sludge gas is not produced to maintain the required temperatures. When sufficient auxiliary fuel may require a considerable expenditure, digestor temperatures are permitted to remain relatively low with consequent impairment of digestion of scum solids. Under these circumstances the best that can be done is to maintain the scum as thin and wet as possible, maintain the digestor at the highest temperature consistent with reasonable expense and also keep it at proper alkalinity as determined by pH or alkalinity tests or both. Considerable work has been done recently to provide more efficient transfer of heat into digestors, including units for preheating of raw sludge, but these newer developments have not as yet found extensive use in digestor construction and remodeling.

Maintaining Proper Alkalinity in the Scum

The pH tests should be made at least twice a week to indicate conditions of alkalinity or acidity in the sludge, supernatant and scum layers. Alkalinity tests are also of value although they are usually omitted at the smaller plants. The digestive organisms usually thrive best when the pH is at or slightly above the neutral point, 7.0, although many digestors will function well at a pH of 6.8 or even 6.7. In the newer concepts of digestor operation, the use of lime is frowned on under any conditions. Where lime has been added at regular intervals to maintain a satisfactory pH, it has generally not been used when the total alkalinity is ample even when the pH drops below 6.7, and if added at all should be discontinued when the pH rises above 7.0. A pH of 8.0 or over is usually indicative of free caustic, which will kill off desired digestive organisms, while a pH of 6.5 or less indicates sufficient acidity to inhibit desired organisms.

If lime is used, it may precipitate into the sludge and give it an undesirably high pH, thereby interfering with sludge diges-

tion while the supernatant has a pH of around 7.0. This condition can be remedied by recirculating the bottom sludge into the supernatant. Usually when the scum is kept thin and wet it will have about the same pH as the supernatant, but if it becomes thick and compact and contains an appreciable amount of raw solids, the pH may become lowered to 5.5 or less. From a practical standpoint the most advisable corrective procedure is to maintain the pH of the supernatant somewhat above 7.0 and keep the scum wet with it rather than try to add lime solution directly to the scum in which it may concentrate in spots without exerting extensive acid neutralizing influence or may even provide caustic destruction of digestive organisms.

Location of Scum and Sludge Layers

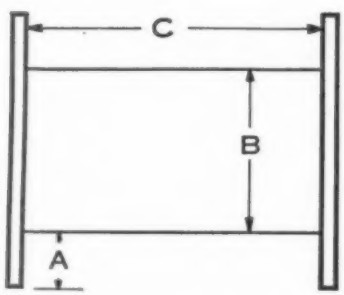
Digestor operation can be helped greatly by frequent measurements to determine the location of scum and sludge layers, thus giving the thickness of scum, sludge and supernatant layers. Unfortunately such measurements with bottle sampling outfits are messy and time consuming, while measurements with plunging rods can easily develop too great an error for reliability.

Some digestors are equipped with a battery of sampling pipes at different levels and if daily samples are taken from these pipes and allowed to settle out for ten minutes the sludge elevation can be estimated approximately between the highest sample showing sludge and the lowest sample showing supernatant, while the scum elevation can be estimated between the highest sample showing supernatant and the lowest sample showing scum. Occasional check measurements with bottle sampling outfits should be made to verify these estimates and provide corrective factors if necessary. If the sampling pipes are not more than two and a half feet apart vertically in the digestor, the error in thus locating the sludge and scum lines will probably be less than a foot and the estimation would therefore be of sufficient accuracy for all practical purposes. When the sampling points are spaced at a greater vertical interval, a greater error will be obtained, and a more accurate method must be used than merely observing the samples for interpolating the scum and sludge elevations between the proper sampling points.

When daily records can be obtained of location and thickness of scum, sludge, and supernatant layers they will give a check on the effectiveness of various digestor operations and also act as a guide in indicating when and how much sludge to draw off, what scum operations are required, what level to use in drawing off supernatant and help explain the actual functioning of the digestor. The scum problem is so closely tied in with all other phases of digestor operation that it is really necessary to have a good picture of digestor conditions and functioning in order to solve the scum problem satisfactorily, and this picture can be best obtained by frequent measurements giving the location and thickness of the various layers in the tank.

Summary

Briefly summarizing the foregoing considerations, one finds that the scum problem as seen from the operating standpoint consists of establishing proper digestion conditions for the material which rises to the top of the digestor, more difficulty being encountered with overloaded digestors than with those of ample size. The most important of these conditions is a proper temperature in the scum as well as in the rest of the digestor, a scum temperature of at least 95° F. being preferable if it can be obtained at reasonable cost. The next most important condition is a proper alkalinity, a pH slightly above 7.0 being preferable if obtainable, a pH of 6.8 being acceptable otherwise. With satisfactory conditions of temperature and alkalinity, proper seeding of the scum with digesting organisms will complete the major requirements for scum digestion. The key to the solution of the scum problem lies in keeping the scum thin and wet to allow favorable digesting conditions to become prevalent. Undigestible material must be physically removed from the digestor. The operator can only hope to solve his own particular scum problem by efficient operation of the digestor as a whole, and, to secure and check such operation, frequent determinations of the location and thickness of scum, sludge and supernatant layers are required.



FORMULA:— $L = (A + B) \times A \times C \times K$

L = Length of rope in feet.

A = Depth of flange in inches. In computing capacity of reels "A" is reduced 1½" to 2" to provide for a clearance.

B = Diameter of drum in inches.

C = Width of drum in inches.

K = Constant which is given below for a given size of rope.

Rope Dia.	Value of "K"	Rope Dia.	Value of "K"
1/32	266.24	7/8	.342
1/16	66.56	1	.262
3/32	29.76	1 1/8	.207
1/8	16.64	1 1/4	.167
5/32	10.76	1 3/8	.138
3/16	7.44	1 1/2	.116
1/4	4.16	1 5/8	.099
5/16	2.67	1 3/4	.085
3/8	1.86	1 7/8	.074
7/16	1.37	2	.066
1/2	1.05	2 1/8	.058
9/16	.828	2 1/4	.052
5/8	.672	2 3/8	.046
3/4	.465	2 1/2	.042

DETERMINING YARDAGE ON REELS OR DRUMS

Although the formula was designed for computing the length of cable, etc., of various diameters, which a reel or drum of given dimensions will accommodate, the method is equally valuable for determining footage remaining on a reel or drum, for inventory purposes or other reasons. In such instances the depth (A) is the depth (in inches) of rope, cable, wire, etc., remaining on the drum or reel.

Example: Assume a reel having a 5 in. core (B) and a width of 10 in. (C). The material is ¼ in. in diameter and its depth on the core is 2 in. (A).

$$(B + A) \times A \times C = X$$
$$(5 + 2) \times 2 \times 10 = 140$$

Now refer to table of factors for the "K" value for ¼ in. materials. such being 4.16 ∴ The footage is $140 \times 4.16 = 582$ ft. or, if ½ in. material $140 \times 1.05 = 147$ ft.

If it is desired to determine the length of rope, wire, rubber hose, copper tubing, packing, caulking yarn, etc., wound on a drum or reel, the accompanying formula will prove very helpful.

The sketch, with formula and factors, appeared in Wire Rope Cat. No. 20 of the Hazard Wire Rope Div. of American Chain and Cable Co. Inc.

THEORY AND OPERATION OF SEPARATE SLUDGE DIGESTION UNITS*

By L. L. LANGFORD

Eastern Sales Manager, Pacific Flush Tank Co., New York, N. Y.

WHILE our ultimate object is to solve specific individual sludge digestion problems, let us begin with an attempt to learn something of the reasons why. Why does sludge digest? Why does it *not* digest? Can we logically hope to "lift the curtain" in an endeavor to view the "behind the scenes" activity within a separate sludge digestion tank?

Let us consider first the practical accomplishments of sludge digestion. They are, briefly (a) reduction in volume; (b) improved ability to drain and dry, and (c) reduction or complete elimination of offensive odor.

What Is Digestion?

The digestion of sludge is primarily a matter of biochemistry. Now what does that mean?

One definition would be the study of the composition of life substances and the changes of composition which they undergo. In connection with this subject, the life referred to is bacterial life. According to Hotchkiss[1] sewage contains many types of bacteria capable of producing ammonia and hydrogen sulfide from proteins. These are one of the groups of bacteria in sewage in which we are particularly interested. In general, it is the action of such bacteria and protozoa on the organic compounds that brings about the changes which take place during digestion.

Sludge is comprised of organic and inorganic constituents. The organic compounds include, under the heading of carbonaceous material—sugars, starches, cellulose, lignins, etc., and under heading of nitrogenous material—proteins, urea, amino acids, etc. There are also, of course, the fats, including vegetable, animal and mineral. Also, we must not overlook the important fact that water, as the basic element of the sewage from which the sludge is derived, is of great importance together with the bacteria which the sludge contains.

The problem of sludge digestion therefore resolves itself into ascertaining and maintaining an environment which will favor and stimulate the activities of desirable bacteria, and at the same time eliminate or arrest the activities of all undesirable forms, Max Levine.*

We are naturally interested in the power of bacterial multiplication. This is markedly affected by (a) any change in behavior of an organism in response to a stimulus, (b) the oxygen content and (c) the nature of available food supply of their environment. The bacteria function as catalysts through the agency of enzymes. Now catalysis has to do with the acceleration or retardation of a chemical reaction by a substance which itself undergoes no permanent chemical change, or which may be recovered when the reaction is completed.

Enzymes

The next logical question would be, What are enzymes? Briefly, they are complex organic substances effecting reactions which otherwise would not occur, *e.g.*, fermentation. The action of enzymes is selective, one class hydrolyzing carbohydrates, another proteins and a third class esters. A few enzymes are found in natural secretions such as digestive juices, but more often they are obtained only from the interior of cells. Although much is not known of their chemical composition, they are reported as essentially colloidal in nature. Their function is to convert insoluble substances into compounds of lower molecular weight, through the incorporation of a molecule of water, and then splitting. There are enzymes which split fats into glycerol and fatty acids, others which break down proteins and similar complex constituents into amino acids, and yet others which are associated with hydrolysis of the complex carbohydrates into the simple sugars.

Since oxidation plays a major role in sludge digestion, we might properly inquire as to what occurs. Oxidation involves the addition of oxygen to a compound. More generally, it is any reaction which involves the loss of electrons from an atom.

According to Warburg,[2] biological respiratory oxidation takes place through the catalytic transfer of molecular oxygen, which is alternately oxidized and reduced, to the substance being oxidized. Molecular oxygen is therefore the essential and active element.

Wieland,[3] on the other hand, considers the phenomenon characteristic of biological oxidation to consist of the loss of hydrogen.

As pointed out by Waksman,[4] "the extent of decomposition of carbohydrates by micro-organisms is found to depend not only on the nature of the organisms, but also on the nature and amount of available nitrogen. For every unit of carbon decomposed as a source of energy, a certain amount of nitrogen is assimilated, whether the latter is present in the form of protein, simple protein degradation products, or inorganic salts."

From the standpoint of anaerobic oxidation effected in the course of sludge digestion, it is particularly significant that water not only serves as a disbursing medium in which the bacteria act upon the dissolved sewage constituents, but also enters into oxidation reactions.

In this regard, Dr. H. Bach[5] in a private communication points out that in order to become decomposed, sludge particles must be totally immersed in water, allowing the bacteria an unrestricted supply of this essentially indispensable liquid; for, as he observes, the bacterial body itself consists of far more than 90 per cent of water. He further emphasized the importance of protecting the bacteria from the access of oxygen in order to insure *true* anaerobic action, his thought being that only this kind of bacterial action results in breaking up the sludge particles in their *depths*, as compared to aerobic action, which is to his mind always confined to the *surface* of particles and therefore may be employed only in cases where undissolved suspended matters, if at all present, are in at least minute amount, and in minute particle sizes. Another point emphasized by Bach is the necessity of protecting the bacteria from the permanent influence of products formed in the course of the bacterial actions, as a refuse of the bacterial cell or as the result of splitting action of bacteria on a substance. His thought is that carbon dioxide is especially poisonous to bacteria of any kind. He points out that carbon dioxide is split away from fatty acids, with the rest of the substance becoming transformed into methane, thus accounting for the fact that sewage sludge gas may contain some 30 per cent of carbon dioxide.

From this will be observed the value and the importance of maintaining submergence of all material to be digested at all times.

Many organic substances (carbohydrates, fatty acids, proteins) are fermentable to carbon dioxide and methane, when added to an active sewage sludge seed. "Buswell, Fair and Rudolfs, with their collaborators, have differentiated the effect of environmental conditions—temperature, reaction, concentration of inorganic and organic constituents—upon the rate of methane production, but investigations on the roles of the various bacteria in such fermentation mixtures are rather meager.

"Organic acids constitute a primary end-product of decomposition of the amino acids and this is also true with reference to the first stages of decomposition of carbohydrates. If conditions in the environment preclude the further rapid oxidation of these acids, they will accumulate and interfere with the train of biological transformations." To speak more practically and less theoretically, and as pointed out also by Bach, the layer of "top sludge" at the surface of the contents of a sludge digester, partly or temporarily forming a crust penetrating into the sludge gas atmosphere, obviously is in reverse to the conditions stipulated, due to a lack of water on one side and the presence of carbonic acid poisons on the other.

Again, the action which progresses in sludge digestion is brought about through the use of the organic matter as bacterial food. The material is liquefied by secretions of the bacteria, known as enzymes. The liquid is then absorbed in the bacterial cell, where changes occur which cause the cells to grow and multiply by splitting them up into parts. Each part in turn becomes a new focus of life and eventually splits again. Optimum conditions must be provided for growth of the organisms which accomplish the decomposition as well as for the proper biological, physical and chemical environment. Numerous investigations of the favorable factors in digestion have demonstrated that control of the temperature is a more important factor than pH control.

Foaming

Injurious action due to rapid bacterial growths or excessive microbial action is associated with such phenomena as acid fermentation, generally referred to as foaming. Acids are formed as the primary fermentation products of carbohydrates, fats and proteins. In a properly functioning digestion tank these organic acids are further broken down to carbon dioxide and methane. Where the rates of acid production in the primary stages of fermentation are greater than the rate of methane production, there may then be a tendency for

*Presented at Lecture-Laboratory Course on Sewage Treatment and Disposal, sponsored by Pennsylvania Sewage Works Assn. at St. Joseph's College, Philadelphia, Pa., May, 1945, and reprinted here from *Sew. Wks. Jour.* by permission of F.S.W.A.

the development of acidity. Acidities greater than pH 6.4 markedly interfere with methane fermentation and higher acidities (pH 5.5 to 6.0) retard, and may even stop the breaking down of the proteins.

For best results, therefore, digestion tanks should be operated to maintain a slightly alkaline reaction. The presence of carbohydrates in any appreciable quantity markedly accentuates the tendency toward acidity, whereas the presence of alkaline salts, such as are found in hard waters, or of humus-like bodies associated with well digested sludge, serves as a buffer against the development of detrimental acidities.

As a remedial and control measure the increments of fresh solids added should be restricted to a point where the acidities developed in the first stages of decomposition will not exceed the buffer value of the water and the sludge.

Loadings

This brings us to a consideration of digester loading, which might preferably be referred to by the expression of "lb. of dry solids added per cu. ft. of tank capacity, per 30-day period." Such loadings at Cedar Rapids, Iowa, for example, have been increased from an average of 4.3 lbs. of dry solids added per cu. ft. per 30 days to 5.5 lbs. for a 30-day period, 6.4 lbs. for a 15-day period and as high as 9.0 lbs. for a shorter 5-day period.

A composite study of peak loads, obtained from data taken at Chicago, Cleveland, Columbus, Syracuse, Rochester and other large American cities, as assembled by R. A. Alton of Columbus, Ohio, results in a curve showing maximum raw sludge production varying from about 140 per cent over a 40-day period up to about 400 per cent for a 2-day period.

Again, loadings must be considered in respect to volatile solids, for, as W. Vincent Barry, city engineer of New Haven, Conn., has so graphically illustrated recently, the percentage of volatile solids in the total (settleable) suspended solids (after 2 hours' detention) is but a fraction of those available in the total solids of a medium strength sewage. It is further of interest to note that the reduction of solids by digestion, as expressed in terms of volatile solids reduction, depends largely upon the per cent of volatile matter in the material fed to the digester. For example, with only 60 per cent of volatile solids in the raw sludge, reduction of the original volatile matter in the digested sludge when ripe is only about 47 per cent, whereas with 70 per cent volatile in the raw, a reduction of about 67 per cent may be anticipated, based upon results as reported at 14 typical sewage treatment plants.

Operation

Sludge additions should be made to each primary digestion tank as frequently as possible or as is feasible. By adding smaller quantities at more frequent intervals, a more constant food supply is afforded the bacteria and a more uniform gas production is obtained, which indicates a more uniform rate of digestion.

Sludge withdrawals should be made in small increments, drawing only one sludge bed or less at a time. It has been noted that frequently when operators find a digestion tank loaded with solids, with little supernatant liquor present and a preponderance of so-called "floating sludge" on top, they resort to withdrawing a large quantity of low volatile content or digested sludge from the bottom of the tank. The result is generally an aggravating of the situation due to an upsetting of the tank balance with an increase in the "floating sludge" layer both as to thickness and concentration.

In a two-stage system care must be exercised in transferring material from the first or active tank to the second or concentrating-separation tank. Best digested solids should not be depleted since they are necessary not only for seeding and buffering of the added raw solids, but act as a "roughage" material recently found necessary for proper environment for the organisms to work effectively.

In the operation of digesters, lime is commonly employed as a means of pH control, and it has been recognized that frequently such application of lime has been overdone. It must not be overlooked that its application may increase the volatile acids, and also that it may have bactericidal properties, thus harming rather than assisting in the desired tank activity.

We would stress the importance of never losing sight of the fact that each plant is a distinct and individual problem and that the methods of operation for any particular plant must be proven empirically. This is not to say that certain fundamentals of operation do not apply; as long as they are fundamentals—as long as they conform to the biochemical requirements—they may properly be practised. As a case in point, the maintenance of liquefactive conditions is fundamental. This state may have to be maintained artificially in respect to the scum or top sludge zone. Constant scum submergence is imperative, and the introduction of hot supernatant liquor or sludge taken from the active zone of a tank is in a majority of cases found extremely effective as an operational measure, as pointed out by Buswell in his application for patents covering such practice.

Loadings and the per cent of available volatile material will both be reflected in the gas production, with respect to total quantity and rates of production. In this connection, gas production can effectively be reported for the records in terms of cu. ft. per lb. of volatile solids added, as well as per cu. ft. of tank capacity per 30-day period, and in this way be tied in with digester loadings, based on either total or volatile solids, in lb. per cu. ft. per 30-day period.

The importance of the maintenance of ample buffer material in the form of relatively well digested sludge; the reasonably prompt intermixing of fresh material and sludge or sludge liquor containing large numbers of virile micro-organisms of the types we have been considering as necessary; the maintenance of proper temperature and the immediate removal of the gas produced, on account of its poisonous reaction and drying effect and thus retardation of the digestion process—these are matters of a practical nature which must be considered, and it is hoped that their importance will be better understood in the light of the preceding theoretical considerations.

References

[1]Hotchkiss, M., "Studies on the Biology of Sewage Disposal," *J. Bact.*, **9**, 455 (1924).

[2]Warburg, O., Berlin (1928).

[3]Wieland, H., and Berthe, A., *Ann. de Chemie*, **467**, 95 (1928).

[4]Waksman, S. A., "Principles of Soil Micro-Biology," Second Edition. Williams and Wilkins.

[5]Bach, H., Chemist, Berlin.

[6]Levine, Max, "Bacteriological Aspects of Sewage Treatment" (1938).

PROTECTION OF MOTORS AND CONTROLS AGAINST MOISTURE

By H. V. CRAWFORD
Applications Engineer
General Electric Company, Schenectady, N. Y.

RARE indeed are plant operators who fail to realize that the proper protection of their motors and controls is of utmost importance. Most operators know only too well how important it is to keep motors and control equipment from becoming overheated from internal or external sources. The dangers resulting from inadequate lubrication are also rather well known, but the dangers resulting from over-lubrication also should be clearly understood by every operator. This is extremely important, since accumulations of oil or grease, because of over-lubrication, will rapidly injure the winding insulation of motors.

Even after these considerations have been properly recognized, full protection will still not be provided unless the danger from moisture is adequately stressed. Almost every operator realizes that rain and water must be kept from dripping or splashing on motor windings. All motors installed in the open, or where splash or spatter may occur should be of the totally-enclosed type, with all housing joints properly machined, fitted, and painted, to prevent the entrance of water. The totally-enclosed fan-cooled motor can generally be used in such cases, unless the motor must be installed where actual flooding may occur and interfere with the operation of the fan.

In practically all cases where motors for water works use can be installed indoors, standard open motors are usually satisfactory. However, in sewage plants—depending upon the process employed—motors of every type of mechanical and electrical construction may be required. Many splash-proof motors have been applied to pumps in water plants simply because it was felt that since the motor was to drive a pump, it should have positive protection from moisture in case of accident.

Practically all motors intended for driving pumps in water and sewage plants may be of the standard open type. For other processes in sewage plants, however, the motors may be of the totally-enclosed (fan-cooled) type to provide protection against water or dust from dried ash or sludge, or of the totally-enclosed, non-ventilated, explosion-proof type to provide protection against explosive sewage gas. Such motors driving digester gas boosters are pictured herewith.

What Constitutes Effective Protection Against Moisture?

While most operators appreciate in a general way the importance of protecting motors from moisture, many of them do not fully appreciate what constitutes just the *right kind* of protection. Just because an outdoor type of motor is totally enclosed, or is of the open type but located in a dry spot, does not mean that the insulation will not deteriorate because of the *absorption* of moisture. On the other hand, neither does it mean that if a small amount of water condensate should accumulate in the bottom of the motor, or that if the motor is located in a room in which high humidity prevails, that the winding will deteriorate because of such moisture.

Consequently, protection from moisture resolves itself into the problem of keeping the insulation from *absorbing* enough moisture to cause deterioration and thus result in the motor burning out. To avoid this condition, the motor should not only be protected from falling or splashing water, but, in addition, it should be installed in a warm room or operated up to normal temperature at least once each week, in order to dissipate any moisture of condensation which may have accumulated on the insulation. This accumulation may be enough under some conditions of installation or mechanical construction to cause the insulation to break down if the motor is operated only infrequently, or is not kept sufficiently warm while standing idle.

The foregoing applies to all motors, but especially to those operating on 550 or 2300 volts and above.

When motors are operated only infrequently and, in addition, are located in an extremely damp place, or in the open where the temperature of the motor housing will vary over a wide range from day to night, adequate protection should be provided by applying heat to the windings when the motor is not in operation. In many storm sewage stations, sewage storm reservoirs, and similar locations where the motors normally are operated only a few times a year, it should be the practice either to run the motors at stated intervals in order to dry them out, or to equip them with space heaters.

Automatic Heat Drying of Motor Windings

It is better still to employ a control system which will automatically supply low voltage to the motor, so that a very small amount of current will flow through the windings when the motor is not in operation. Functioning automatically this arrangement supplies only enough current to keep the insulation dry. It is, therefore, much more efficient than using space heaters. With this arrangement, the heat radiates from the wire and passes out through the insulation. Just as long as the temperature of the insulation is raised above the ambient temperature, the moisture absorbed will not be enough to cause the insulation to deteriorate to the point where it will break down when full voltage is applied to the motor.

When space heaters are used, extra conduit and wiring is necessary in order to apply current to the space heaters. On the other hand the special control system uses the same wires from the starting control to the motor to apply the low voltage to the windings when the motor is idle.

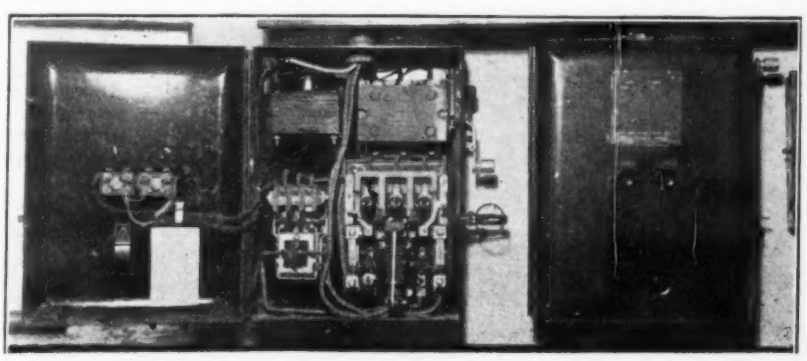
Cost of the System and Its Operation

The cost of the extra control feature is nominal and the savings obtained in power economy will in a short time compensate for the extra cost of the feature. It should be pointed out that the small transformer will supply enough heat to also keep the control equipment in the starter in first class condition.

In regard to the protection of the control, most of the points mentioned for motors apply here also except that space heaters will in most cases meet the requirements. In all cases the control should be enclosed and protected from dripping or splashing water. In general, however, the control is of low voltage, and if operated every few weeks not enough corrosion will result to cause the control to stick. The small amount of heat in the cabinet will keep the insulation on the coils from absorbing sufficient moisture to cause appreciable damage.

It is important that the control should be protected from corrosion caused by sewage gas—principally the hydrogen sulphide present. In the presence of moisture, this is very bad. If a space heater is used and the control is kept warm, corrosion from this gas will be small. However, in order to prevent possible explosion where inflammable gas may be present, the control should be enclosed in an exploision-proof housing such as that pictured. Even then, if the control is not operated frequently, a small space heater inside the casing is advisable. This, of course, can be supplied by employing a scheme similar to the one suggested in the foregoing for motors.

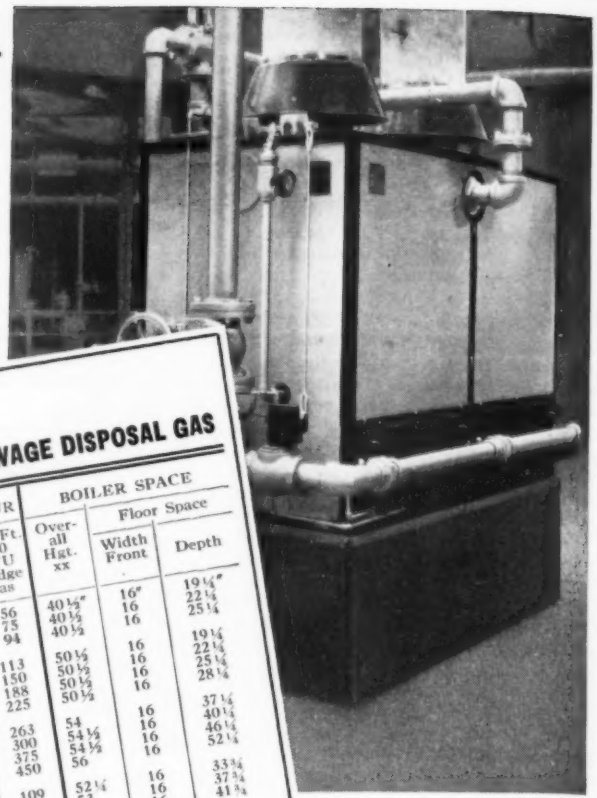
For protection against explosion and corrosion at the same time, oil-immersed control may be used. This type of control is definitely recommended for high voltage equipment. A control which is installed near sludge-drying apparatus, or near sludge or garbage burning incinerators, will sooner or later give trouble not only because of corrosion, but also because of dust accumulation. Consequently, the control should be located in a separate room, or if absolutely necessary, located close to the drying or burning equipment, and fresh air should be supplied from the outside by a small fan exhausting into the control housing. This maintains a slight pressure, say 2 or 3 ounces, inside the housing and prevents the entrance of dust and gas fumes.



"G-E" Special Combination Magnetic Switches for Automatically Applying Low Voltage Warming Current to Motor Windings

For heating sludge digesters

AMERICAN GAS BOILERS



AMERICAN GAS BOILER CAPACITIES WITH SEWAGE DISPOSAL GAS

BOILER NO.		OUTPUT PER HOUR			INPUT PER HOUR		BOILER SPACE		
								Floor Space	
Steam	Water	BTU per Hour	Sq. Ft. Steam A.G.A. Rating	Sq. Ft. Water A.G.A. Rating	BTU per Hour	Cu. Ft. 700 BTU Sludge Gas	Overall Hgt. xx	Width Front	Depth
.....	1-GA-4E	31,500	.....	210	39,350	56	40½"	16"	19¼"
.....	1-GA-5E	42,000	.....	280	52,500	75	40½	16	22¼
.....	1-GA-6E	52,500	.....	350	65,600	94	40½	16	25¼
.....	2-GA-4E	63,000	.....	420	78,750	113	50½	16	19¼
.....	2-GA-5E	84,000	.....	560	105,000	150	50½	16	22¼
.....	2-GA-6E	105,000	.....	700	131,200	188	50½	16	25¼
.....	2-GA-7E	126,000	.....	840	157,500	225	50½	16	28¼
.....	4-GA-8E	147,000	.....	980	183,750	263	54	16	37¼
.....	4-GA-9E	168,000	.....	1120	210,000	300	54½	16	40¼
.....	4-GA-11E	210,000	.....	1400	262,500	375	54½	16	46¼
.....	4-GA-13E	252,000	.....	1680	315,000	450	56	16	52¼
.....	.....	61,200	255	.....	76,600	109	52¼	16	33¾
.....	.....	81,600	340	.....	102,000	146	53	16	37¾
.....	.....	102,000	425	.....	127,500	182	52½	16	41¾
0-GS-4E	.....	146,000	610	980	182,500	261	54½	35	25
0-GS-5E	.....	186,000	775	1240	232,500	332	56¾	39	25
0-GS-6E	.....	225,000	940	1500	281,500	402	56½	43	25
1-GS-4	1-GW-4	265,000	1105	1770	331,000	473	57	47	25
1-GS-5	1-GW-5	305,000	1270	2030	381,000	545	59¼	51	25
1-GS-6	1-GW-6	344,000	1435	2300	431,000	616	58½	55	25
1-GS-7	1-GW-7	384,000	1600	2560	480,000	686	59¼	59	25
1-GS-8	1-GW-8	424,000	1765	2820	530,000	757	59	63	25
1-GS-9	1-GW-9	480,000	2000	3200	600,000	857	74	53	41½
1-GS-10	1-GW-10	576,000	2400	3840	722,000	1030	75	58	41½
1-GS-11	1-GW-11	672,000	2800	4480	840,000	1200	77	62	41½
4-GS-6	4-GW-6	768,000	3200	5120	960,000	1372	77¾	66	41½
4-GS-7	4-GW-7	864,000	3600	5760	1,079,000	1543	79½	70	41½
4-GS-8	4-GW-8	960,000	4000	6400	1,200,000	1715	80	74	41½
4-GS-9	4-GW-9	1,152,000	4800	7680	1,440,000	2060	75	85	41½
4-GS-10	4-GW-10	1,344,000	5600	8960	1,680,000	2400	77	93	41½
4-GS-11	4-GW-11	1,536,000	6400	10,240	1,920,000	2740	77¾	103	41½
4-GS-13	4-GW-13	1,728,000	7200	11,520	2,162,000	3090	79½	107	41½
4-GS-15	4-GW-15	1,920,000	8000	12,800	2,400,000	3425	80	110	41½
4-GS-17	4-GW-17	2,016,000	8400	13,440	2,520,000	3600	77	136	41½
4-GS-19	4-GW-19	2,304,000	9600	15,360	2,880,000	4120	77¾	148	41½
4-GS-21	4-GW-21	2,592,000	10,800	17,280	3,240,000	4625	79½	160	41½
4-GS-22	4-GW-22	2,880,000	12,000	19,200	3,600,000	5145	80	172	41½
4-GS-25	4-GW-25	3,072,000	12,800	20,480	3,840,000	5480	77¾	186	41½
4-GS-28	4-GW-28	3,456,000	14,400	23,040	4,320,000	6165	79½	202	41½
4-GS-31	4-GW-31	3,840,000	16,000	25,600	4,800,000	6850	80	218	41½
4-GS-33	4-GW-33								
4-GS-37	4-GW-37								
4-GS-41	4-GW-41								

xx To top of Draft Hood

American Gas Boilers for heating sludge digesters are engineered for dependable operating and are especially adapted for burning sewage gas. They are completely automatic—one valve controlling water temperature to any predetermined degree. Pintype sections afford the most effective type of cast iron heat-absorbing surface. Controls are available to accommodate any desired system of gas, temperature, or pressure regulation. A wide range of sizes meets all requirements. For complete details of these performance-proved gas boilers, as well as information about American Gas Fired Automatic Storage Water Heaters, write American Radiator & Standard Sanitary Corporation, P. O. Box 1226, Pittsburgh 30, Pa.

AMERICAN-Standard

HEATING PLUMBING

Serving the Nations' Health and Comfort

SALES OFFICES IN PRINCIPAL CITIES

OPERATING AND EXPERIMENTAL OBSERVATIONS ON DIGESTION OF GARBAGE WITH SEWAGE SOLIDS*

By David P. Backmeyer
Superintendent of Sewage Treatment, Marion, Ind.

THE data and discussion material in this paper are divided into two sections or parts. The first consists of a brief description of the garbage grinding and disposal facilities at the Marion sewage treatment plant, together with some operation figures which are intended to illustrate what dual disposal has done both to and for the treatment plant during the past five years. The second part is a brief review of a series of experiments that were conducted with small digestion units of 25 gallons each. This latter work is not yet completed, and more information will be available from it later.

Dual Disposal Experience

About five years ago the first motorized collection equipment was purchased and put into use by the city garbage department. As the then recently completed sewage treatment plant was equipped for grinding and disposing of garbage, city officials at that time were anxious that this equipment be given a fair trial, in an effort to find a sanitary method for final disposal of the garbage. In the month of May, 1941, 18 tons of green garbage were brought to the plant for grinding as a first test of the facilities provided in the original plant.

Handling of Garbage

The garbage disposal installation was more thoroughly tested during the next few months. In September of the same year 162 tons of green garbage were ground and added to the raw sewage at the wet well. The method of handling the garbage at the plant was extremely simple. The garbage was dumped from the trucks onto the grade floor and then shoveled into the grinder hopper. Tin cans, trash, crockery, pieces of metal, etc., were sorted out as the garbage was shoveled.

The ground garbage was discharged from the Jeffrey garbage grinder to the raw sewage wet well beyond the sewage screens. The raw sewage pumps then discharged the garbage solids with the sewage solids to the grit channel for the removal of sewage grit and garbage mineral matter. Preaeration tanks at the head end of the primary tanks afforded a means of releasing the grease for removal by skimming at the effluent ends. The main bulk of the garbage solids was removed as sludge with the sewage solids, and pumped to the digesters for digestion.

Three definite problems soon arose from this method of handling the garbage solids. First, an excessive amount of time was required for drawing sludge from the primary tank sludge hoppers. When seven or eight tons of garbage were handled in one day, one operator would spend most of the day getting the sewage-garbage sludge mixture into the digesters. Secondly, the load on the secondary treatment, which is by activated sludge, was found to be considerable as a result of the release of colloids and solubles from the finely ground garbage. In the third place, a large amount of floating material would get past the grease skimmers and make an unsightly mess when it would collect on the wiers of the final settling tanks. The answer to these problems seemed to lie in the development of a system in which the garbage could be gotten into the digesters without first mixing it with the sewage.

In May of 1943 the flooded condition of the Mississinewa River permitted by-pass of the flow to the treatment plant for a few days, and during this period a portion of the raw sewage wet well was partitioned off for use as a separate garbage well. The necessary piping was installed for removal of the garbage, and for cleaning out the residue from the bottom of the well. The general plan of the well as it is being used today is shown in Fig. 1.

Several changes in the method of mixing the ground garbage have been made in the past two years. The agitation in the well must be sufficient to prevent the garbage solids from "caking" at the surface of the accumulation, this trouble being more pronounced during the corn canning season. If the ground garbage is left in the well for a period of 10 to 24 hours, lime must be added to control the pH. Two bags of hydrated lime (100 lb.) are usually sufficient to hold the pH above 6.0 when the 3,600-gal. batch is not pumped to the digesters for a period of 18 to 24 hours.

Gas Production and Utilization

If the process of disposal of garbage by digestion with sewage solids is to be an economical one, some practical use must be made of the gas produced.

A study of the data on hand at Marion would indicate that an average yield of 260 lb. of volatile solids from a ton of green garbage should produce 2,600 cu. ft. of gas having a carbon dioxide content of less than 35 per cent by volume.

During the year 1945 the Marion digesters produced 23.6 million cubic feet of

TABLE II.

Results of Garbage Digestion Experiments at Marion, Ind.

Test Number	1	2	3	4	5	6	7	8
Date started	3/10/45	3/10/45	8/30/44	8/30/44	1/16/46	4/23/46	4/23/46	4/23/46
Material digested	Garbage	Garbage	Garbage	Sludge	Garbage	Garbage	Garbage	Garbage
Dry solids (lb.)	1.02	1.02	2.74	2.66	5.17	0.55	0.55	0.55
Volatile solids (lb.)	0.92	0.92	2.45	1.25	4.74	0.48	0.48	0.48
Seed material	Digester supern.	Digester supern.	Water supern.	Water supern.	Digester supern.	From Test 5	90-day supern.	90-day supern.
Temperature (°F.)	79	79	90	89	116	84	80	80
Total gas (cu. ft.)	11.48	13.05	18.93	9.02	38.6	8.8	7.53	7.27
Gas per lb. vol. (cu. ft.)	12.43	14.1	7.73	7.2	8.15	18.3	15.7	15.1
Per cent of vol. removed as gas[1]	80.7	99.1	50.3	46.7	52.8	100+	100+	98.6
Gas pressure (in. water)	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75
Per cent of total gas yield in 5 days	73.0	76.3	50.0	78.6	—	38.1	25.2	24.5

[1] 100 cu. ft. gas considered to represent 6.5 lb. volatile solids.

TABLE I.

Data on Garbage-Sludge Digestion at Marion, Ind.

Month	Volatile Solids Loading		Bottom Sludge in No. 1 Digester		Volatile Solids Removed as Gas (lb.)	Volatile Solids Reduction (%)	Raw Sludge Total Solids (%)	Ground Garbage Total Solids (%)	Digested Sludge	
	Pounds	Lb. per Cu. Ft. per Day[1]	Solids (%)	Volatile (%)					Total Solids (%)	Vol. Solids (%)
1945										
April	154,500	0.062	4.55	45.0	109,000	70.5	5.29	6.00	4.19	38.9
May	143,200	0.055	4.36	44.6	116,300	81.4	4.99	5.13	4.55	39.7
June	202,000	0.081	4.00	44.3	136,500	67.5	5.93	4.23	4.22	39.8
July	210,200	0.081	3.94	45.2	150,800	71.7	5.40	4.24	4.07	39.2
August	224,200	0.086	3.37	48.8	145,500	65.0	4.55	4.11	3.74	43.0
September	223,900	0.089	2.98	52.8	160,500	71.7	4.39	5.23	3.18	46.6
October	172,800	0.067	2.84	54.6	118,100	68.4	4.09	4.52	3.10	52.1
November	171,300	0.068	3.34	57.5	125,300	73.2	4.66	5.00	3.47	52.9
December	140,200	0.054	3.40	58.7	112,000	80.0	3.86	4.55	3.41	53.2
1946										
January	144,400	0.076	4.90	65.6	110,900	79.0	4.71	5.84	3.17	53.9
February	178,600	0.076	5.05	67.1	110,900	62.0	4.72	6.88	3.71	54.0
March[2]	189,900	0.073	5.16	60.8	132,700	69.8	5.37	7.85	3.55	52.0
April	169,200	0.067	3.44	56.8	130,000	76.7	4.16	9.12	3.54	43.9

[1] Based on primary digester capacity.
[2] Recirculation of bottom sludge started on March 20.

*From *Sew. Wks. Jour.*, Jan., 1947. Reprinted by permission of the Fed. Sew. Wks. Assns.

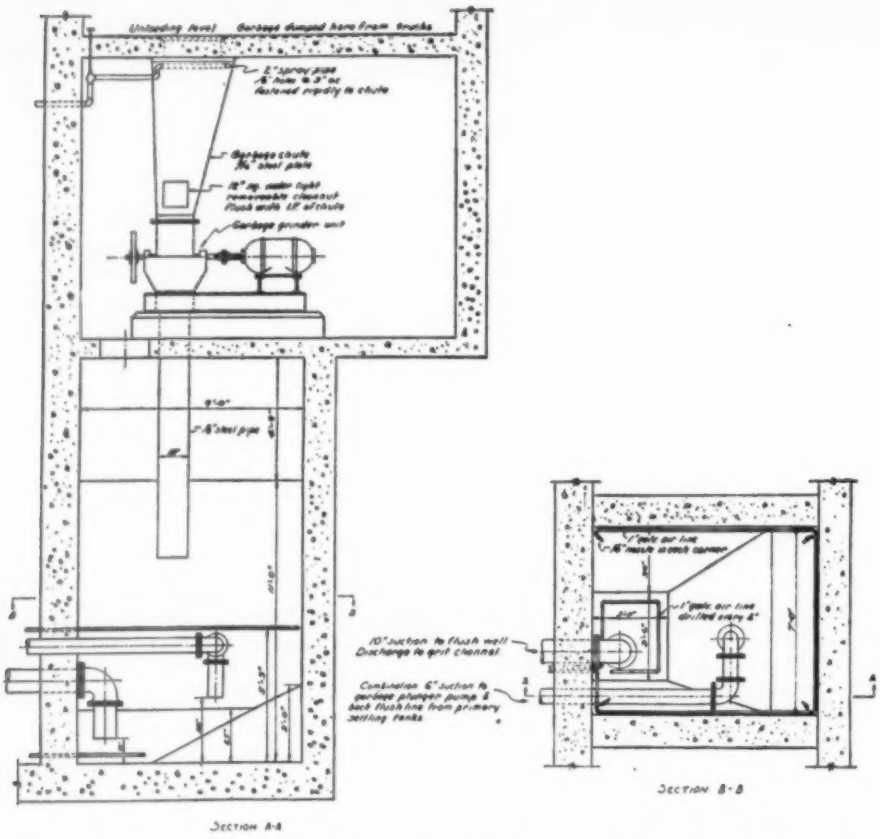


Fig. 1.—Garbage Receiving and Mixing Well at Marion, Ind., Sewage Treatment Plant.

gas, and utilized 21.5 million cubic feet at the gas engines and heating boiler. In addition to the sewage gas used, 640,000 cubic feet of gas was purchased from the utility company to fill in at certain periods when gas production was not sufficient for the total plant load.

Several interesting studies have been made in an effort to determine what percentage of the total gas generated comes from the sewage solids and what part from the garbage solids. Two methods are available for approach to this problem in actual plant operation. If the sewage load is stable, that is, not too far from average with respect to B.O.D. strength as a result of rain water dilution or industrial wastes, the garbage could be taken away for a few days and the resultant drop in gas production noted. By working in reverse order, if the garbage load were stable and the sewage load was reduced by prolonged rains, some indication would be had as to the amount of gas generated from the garbage alone.

The winter months afford an opportunity to study gas production volumes when the amount of garbage handled is very limited. Fig. 2 demonstrates the fluctuation in gas production throughout the calendar year. The curves represent the average of four years' operation by single months. It will be noted that during the first quarter of the year, when the garbage tonnage is below two tons per day, the amount of gas produced is less than 49,000 cu. ft. per day. In the months of July, August and September, the gas yield increases about 30 per cent while the amount of garbage ground increases 400 per cent. It is the writer's belief that more gas would be collected in the summer months if more digestion capacity were provided.

Fig. 3, which is reprinted from the fourth annual report of operations, shows the relationship of the various factors affecting the production of gas during the year 1944. Here the rainfall curve and the canning plant load curve are included, as both of these factors have a definite bearing on the sewage organic load.

Fig. 4 is intended to show the sag in gas yield when rain water washes out the gas-producing sewage solids, and the garbage solids must produce most of the gas. The B.O.D. curve indicates the drop in organic matter in the sewage, with the resultant drop in gas volume from 49,000 to 26,000 cu. ft. per day. Had this "washout" occurred in July, the actual drop would have been about the same, but the range would have been from 75,000 to 52,000 cu. ft. per day. The greatest volume of gas produced in any one single day was recorded in September, 1945, when 97,108 cu. ft. were metered.

In August, 1946, it was possible to study an 11-day period during which time no garbage was taken at the plant. The average daily gas production in this period was 23 per cent below the average for the 15 days preceding the period. The drop was from 68,000 to 52,000 cu. ft. per day.

Digestion Capacity

The matter of digestion capacity, where garbage is to be handled in a sewage treatment plant, is a question of common concern at this time. The term "cubic feet of digester capacity per capita" may be unreliable and misleading for several reasons. Assuming that digestion is carried on at optimum temperature and loading conditions, the variables of organic loading from industrial wastes and the seasonal changes in the garbage itself would necessarily limit such figures to a specific city or town.

The expression "pounds of volatile solids per cubic foot of primary digestion capacity applied per day" would seem to be a much more reliable way to state capacity ratings. Some of the peculiar characteristics of ground garbage may even make this method of comparing capacities questionable.

In referring to the digester loading at the Rahway Valley treatment plant, with sewage sludge only, Fontenelli and Rudolfs* reach the conclusion: "The optimum loading capacity for each 1,000 cu. ft. of primary digestion capacity would be 100 lb. of dry volatile matter per day, producing 50 per cent clear supernatant liquor." At no time during the past two years has the volatile solids loading at the Marion plant reached the 0.10 lb. per cu. ft. per day loading stated above, yet the apparent overloading of the digestion system has pro-

*Sew. Wks. Jour., 17, 4, 692 (July, 1945).

Fig. 2.—Four-Year Record of Gas Production.

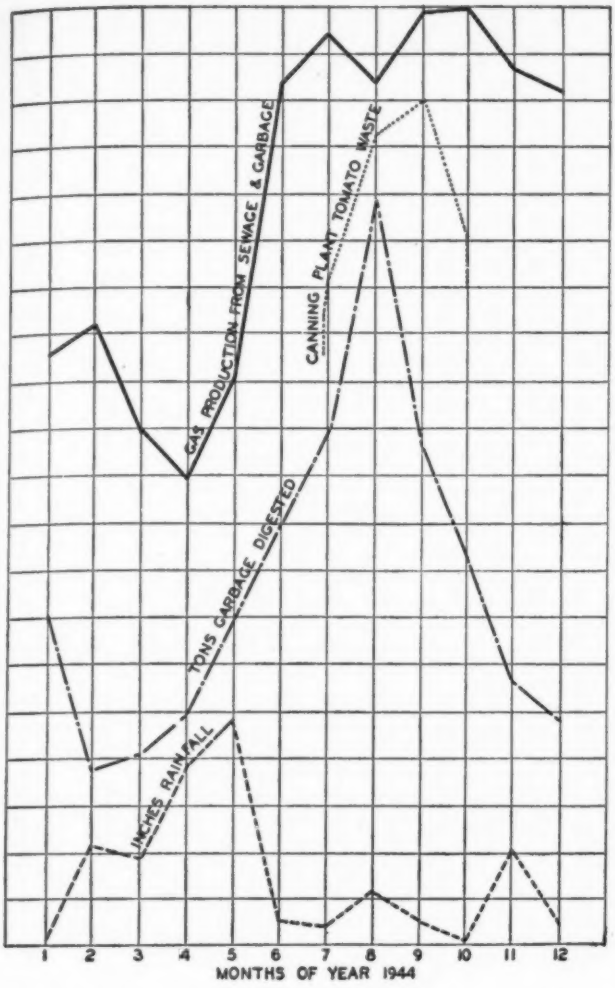

GAS PRODUCTION FROM SEWAGE & GARBAGE
CANNING PLANT TOMATO WASTE
TONS GARBAGE DIGESTED
INCHES RAINFALL
1 2 3 4 5 6 7 8 9 10 11 12
MONTHS OF YEAR 1944

Fig. 3.—Relation Between Garbage Load and Gas Production.

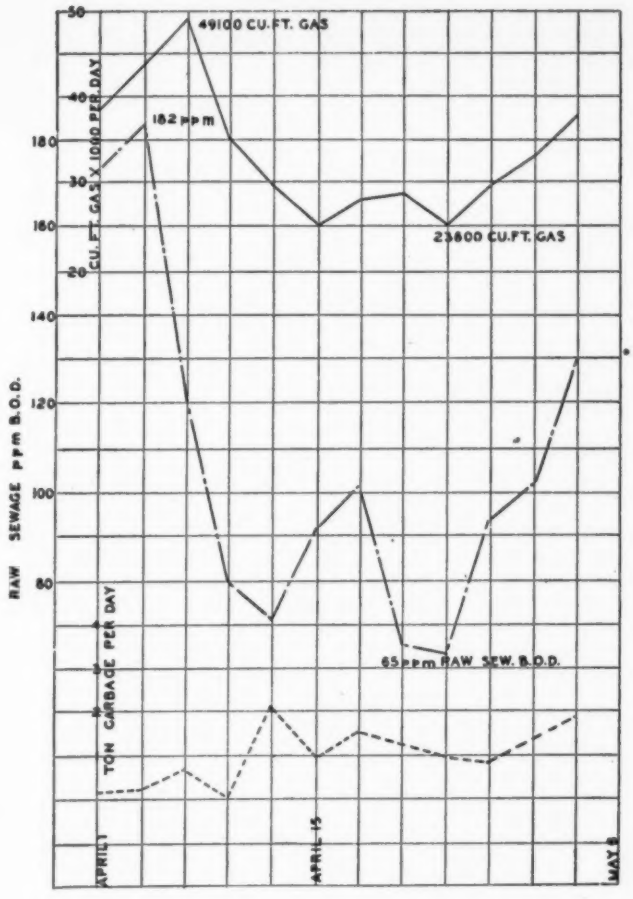


Fig. 4.—Effect of Sewage "Washout" on Gas Production.

duced a supernatant liquor in the secondary digestion tank that will contain 2.5 per cent total solids for several successive weeks at a time. This situation can be accounted for in part by the fact that some of the ground garbage particles are transferred from the primary digester to the secondary digester each day, and as a result the secondary digester is continuously active in producing gas.

It would seem logical that not only the loading of volatile matter, but also the number of cubic feet of gas produced per day per cubic foot of capacity at hand would materially affect the ability of the digester to produce satisfactory supernatant liquor. Fig. 5 illustrates the rather unusual condition which developed in the primary digester during the latter part of 1945.

It will be noted that undigested garbage solids had accumulated in the bottom of the digester, and that very little immediate digestion of these solids was taking place, as is evidenced by the volatile percentage curve which climbed to a peak of 67.1 per cent in March, 1946. The temperature of the sludge at the bottom was surprisingly low at 56° F., while the active sludge above it was 90° F.

The temperature problem was easily solved by circulating the cold, thick sludge from the bottom to a higher elevation, where it could mix with the warmer and more active solids. This circulation resulted in an immediate increase in the amount of gas being produced. The primary digester is now circulated for two hours daily as a routine operation, and the temperature of the sludge at the bottom is above 75° F.

The Marion treatment plant has a designed digestion capacity of 6.25 cu. ft. per capita for the actual 1940 resident population, but on the basis of the 1945 equivalent population, as measured by B.O.D. tests, the present capacity is 4.2 cu. ft. per capita. During the year 1945 only 20 per cent of the sludge and garbage volume put into the system was removed as supernatant liquor.

Throughout the entire month of February, 1946, there was no supernatant in either of the digestion tanks that could be withdrawn. The data in Table I show that although an average of 72 per cent of the volatile solids were removed as gas, the total solids content of the finished sludge

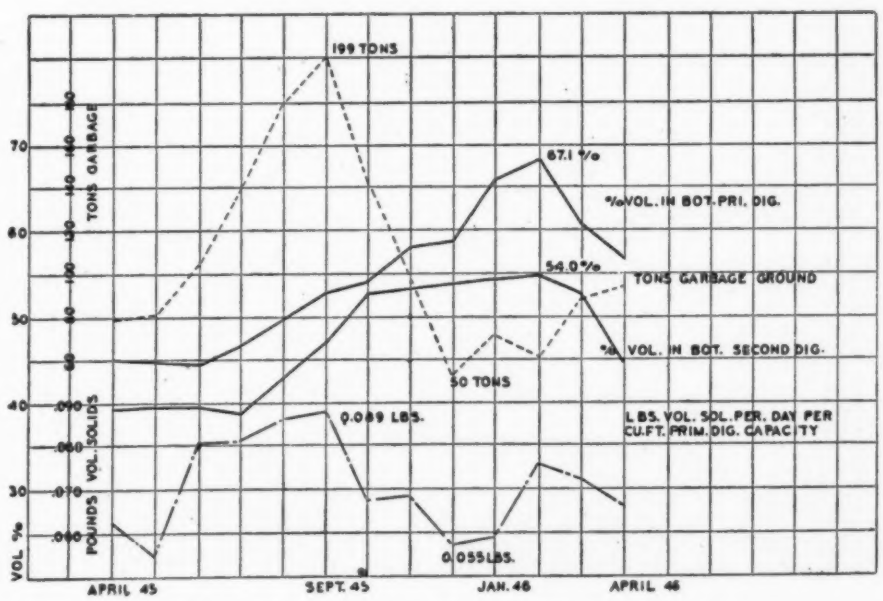


Fig. 5.—Volatile Content of Bottom Sludge in Digesters.

became increasingly lower, and the volatile content progressively increased.

It has been our experience that when the daily gas production is above 0.36 cu. ft. per cubic foot of total digestion capacity, there will be no supernatant liquor in the system that contains less than 5,000 ppm. total solids. At the same time, it does not follow that lower gas yields will always produce supernatant liquor suitable for return to the primary settling tanks.

Some indication of the time required to concentrate the sludge from the secondary digester is given by the results of tests made on the supernatant liquor. By withdrawing the liquor containing 3.0 per cent total solids and allowing it to stand without agitation in 40-gal. drums, it was found that the solids would concentrate to 4.47 per cent in 10 days, to 4.98 per cent in 13 days, and to 5.04 per cent in 24 days. These results would indicate that the sludge in the secondary tank now having a uniform solids content from top to bottom of about 3 per cent would give up about one-third of its volume as supernatant when the concentration of solids reached 5.0 per cent in 13 to 15 days.

The present volume loadings will average about 26,000 gal. of sludge and garbage per day the year through. To get an additional 15 days' digestion time, the present total digestion capacity of 167,000 cu. ft. should be increased 31 per cent to give a total capacity of 219,000 cu. ft. This latter figure would give the plant 8.21 cu. ft. per capita on the basis of the 1940 population, and 5.22 cu. ft. per capita on the basis of the 1945 equivalent population. These populations were 26,700 and 42,000 respectively.

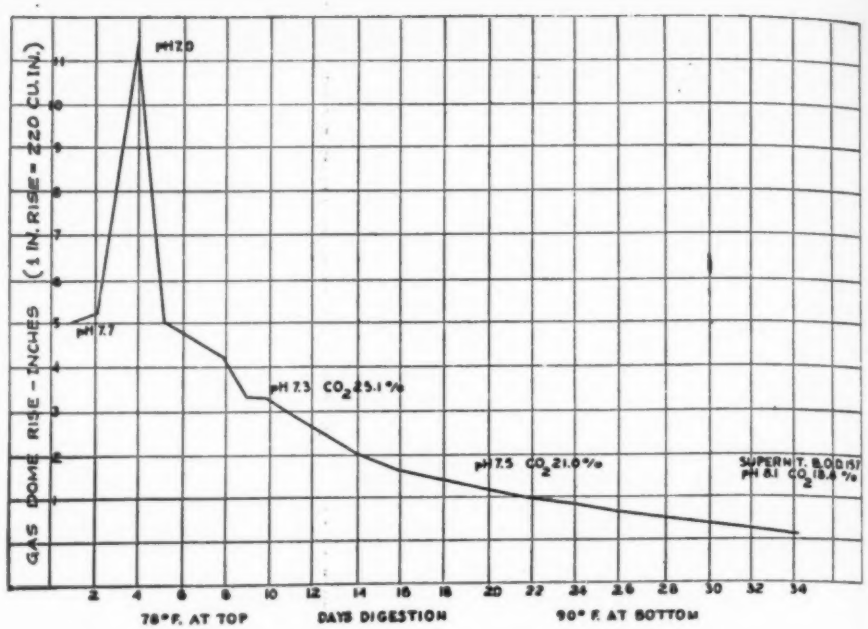

GAS DOME RISE – INCHES (1 IN. RISE = 220 CU. IN.)
pH 7.0
pH 7.7
pH 7.3 CO_2 25.1%
pH 7.5 CO_2 21.0%
SUPERNT. SLUDGE pH 8.1 CO_2 18.4 %
DAYS DIGESTION
78° F. AT TOP
90° F. AT BOTTOM

Fig. 7.—Garbage Digestion Experiment of 34 Days' Duration.

Separation of Grit and Debris

One of the troublesome features involved in adding ground garbage directly to the digesters in preference to mixing it with the raw sewage has been the removal of grit and mineral matter from the garbage. The separate well system shown in Fig. 1 has been used for the past three years at Marion, and no stoppages in pipe lines have been encountered during this period.

The removal of egg shells, bone chips, crushed peach pits, seeds, bottle caps, and various other non-digestible materials by flushing them out the bottom of a properly constructed well would appear to work out in a satisfactory manner. This statement is substantiated by the record of grit removal, which shows that during the eight months of June, July, August and September of 1944 and 1945, the average volume of grit removed per month was 65 per cent above the average removal per month for the full two years. In this same 8-month period the amount of garbage handled per month was 50 per cent above the average tonnage per month for the full two years. Some traces of egg shells, coffee grounds, chicken feathers and other fibrous materials are found in the digested sludge, but not in quantities sufficient to cause caking at the top of the digester or plugging of the sludge draw-off lines.

Fig. 6.—Pilot Digesters Used for Garbage Digestion Experiments.

Summary of Operation Experience

If the garbage disposal installation at Marion has any single quality worthy of special mention, that quality would be simplicity. No special skill or training is required of the men in charge of any part of the installation. The mechanical equipment is confined to two units, the Jeffrey garbage grinder and the Chicago single-piston plunger pump. Both units have performed the functions for which they were installed in an excellent manner.

The following conclusions are based on the five years of experience in digesting sewage sludge-garbage mixtures at the Marion plant:

1. In a properly constructed garbage well, sufficient grit and foreign non-digestible matter may be removed from ground garbage so that the remainder of the garbage solids can be digested with sewage solids without difficulty in a properly controlled digestion system.

2. The gas produced from the digestion of garbage solids with sewage solids is of a quality that will permit its use in gas engines and gas-fired heating boilers.

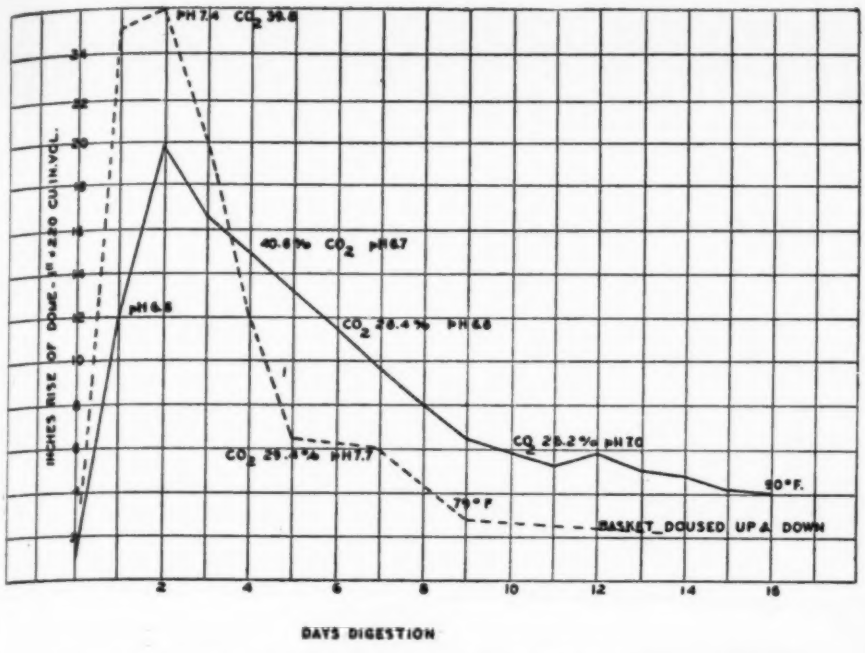


Fig. 8.—Comparison of Results of Two Experiments in Garbage Digestion.

3. The loadings (garbage solids plus sewage solids) of 0.1 lb. of volatile solids per cubic foot of primary digestion capacity per day are too great to allow withdrawal of clear supernatant liquor from the digestion system, with two-stage digestion at temperatures at 90° F.

Digestion Experiments

A previous report of pilot plant experiments on digestion of garbage solids was made in the June, 1946 issue of *Sewage Gas*, published by the Indiana State Board of Health. Some of the previously published data will be included in the summary that follows.

Test Procedure

The equipment used in the experimental work consists of three digestion units as shown in Fig. 6. Each unit was made up of a 25-gal. used paint drum, a sheet metal gas collection dome of about 16 in. diameter and a side wall skirt of 19 in., and a heating unit at the bottom for maintaining temperature control.

The general procedure was to digest raw sewage sludge or ground garbage solids in two of the three drums, and reserve the third unit as a control for the digestion medium. Throughout the course of the tests many variations of this procedure were used.

The top of each collection dome was fitted with a ⅜ in. outlet so that the gas collected could be released and analyzed conveniently. The volume of gas collected was measured by the "inches rise" of the collection domes; the weight of the domes provided a working pressure of 1.75 in. water column on the gas collected.

The results of eight of the tests made are summarized in Table II. Three graphs are shown which demonstrate the gas production rates as measured by the rise of the gas collection dome each day. In Fig. 7 it will be noted that the test was continued for a period of 34 days, but that about 40 per cent of the total gas production took place in the first five days. A supernatant liquor of good quality was obtained at the end of the 34-day period as is shown by the B.O.D. content of 157 ppm.

Fig. 8 shows the results of two tests made over a period of 16 days. In the test represented by the broken line curve, 76.3 per cent of the total gas generated was produced in the first five days of the period. The solid line curve demonstrates the relation of the CO_2 content of the gas to the pH as the digestion rate changes over the 16-day period.

In Fig. 9 the broken line curve represents the digestion of 0.92 lb. of volatile garbage solids in a digestion medium of 135 lb. of digester supernatant having a total solids content of 3.51 per cent. In this test 80 per cent of the garbage volatile solids were accounted for as gas, with the yield being 12.43 cu. ft. of gas per lb. of the garbage volatile solids. The solid line curve in the graph shows the gas production trend when raw primary sewage sludge is digested. In this test 78.6 per cent of the gas was produced in the first five days, and the yield was 7.2 cu. ft. per lb. of the sewage sludge volatile solids.

The loadings in all of the tests were of the "batch" type. Cumulative loading tests are to be made in the future on both the garbage and the raw sewage sludge.

The average of seven tests made with garbage showed that 13.1 cu. ft. of gas were produced from a pound of garbage volatile solids. Without exception, the CO_2 content of the gas was higher at the beginning of the run when the gas production was greater. In digesting samples of spent brewers grain and of cheese whey it was found that the CO_2 content of the gas would rise to 63 per cent at the start of the test, and then drop sharply to a low of 20 per cent after a period of nine or ten days. This would tend to indicate that different types of garbage (due to seasonal variation of diet) might produce a large volume of gas having little fuel value in some cases.

The results of two tests made on raw sewage sludge gave an average of 8.26 cu. ft. of gas per lb. of volatile solids digested. In actual plant operation during the winter months when garbage loadings are low, the yield from garbage and sewage sludge together was 8.12 cu. ft. per lb. of volatile solids. As the actual amount of garbage handled during this part of the year is less than two tons per day, it could be assumed that this value would largely represent gas generated from sewage sludge only.

The tests made to date would tend to indicate that a given weight of volatile material in garbage would produce a greater volume of gas than a similar weight of volatile solids found in sewage sludge. Further investigation is necessary, however, before definite conclusions can be drawn.

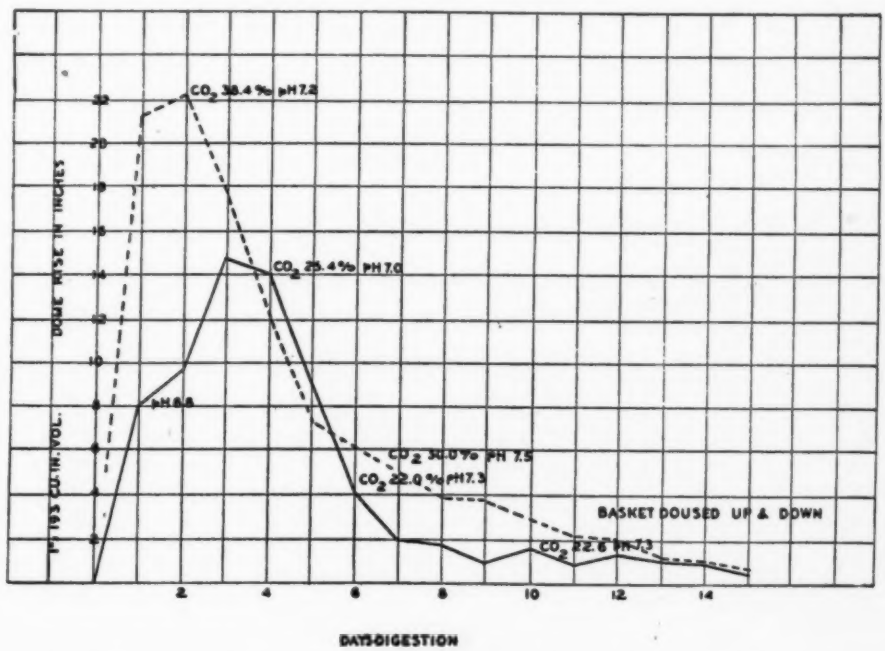


Fig. 9.—Comparison of Results from Garbage and Sludge Digestion Experiments.

THE JEFFREY MANUFACTURING COMPANY

ESTABLISHED 1877

996-99 North Fourth Street, Columbus 16, Ohio

BALTIMORE 2, MD., Munsey Bldg.
BIRMINGHAM 3, 2210 Third Ave., N.
BOSTON 16, 38 Newbury Street
BUFFALO 2, Jackson Building
CHICAGO 1, Bell Bldg.
CINCINNATI 2, Carew Tower
CLEVELAND 13, Rockefeller Bldg.
DENVER 2, Ernest & Cranmer Bldg.
DETROIT 13, 5808 St. Jean Ave.
HARLAN, Kentucky
HOUSTON 5, TEXAS, 3748 Rice Blvd.
HUNTINGTON 19, W. VA.
Guaranty Bank Building
JACKSONVILLE, 4173 Roma Blvd.
MILWAUKEE 2, 735 No. Water Street
NEW YORK 7, 30 Church Street
PHILADELPHIA 3, Broad St. Station Bldg.
PITTSBURGH 22, Oliver Bldg.
SALT LAKE CITY 1, 101 W. 2nd South St.
ST. LOUIS 3, 3015 Locust St.
SCRANTON 3, 122 Adams Avenue

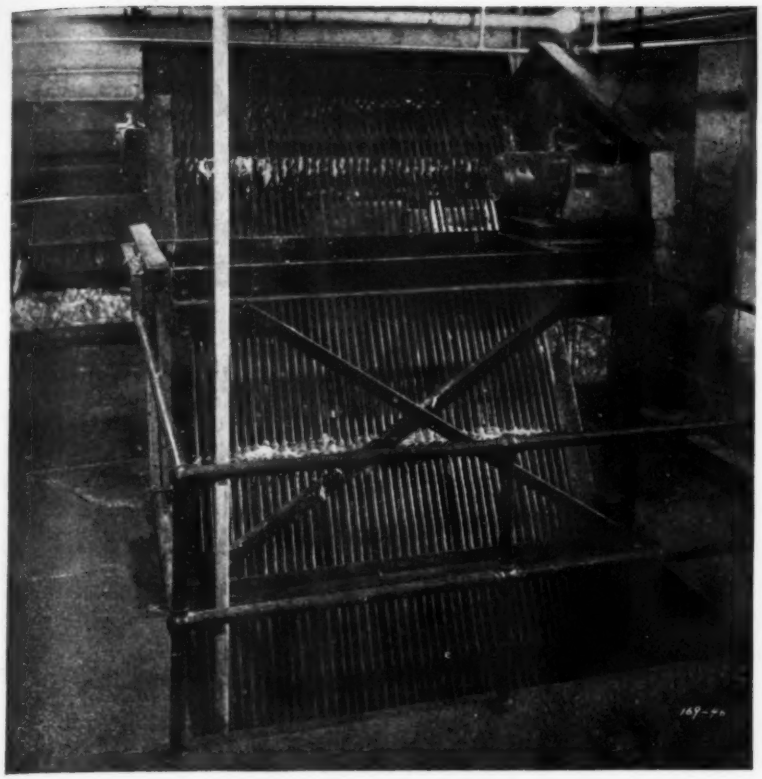
Jeffrey Mfg. Co. Ltd. of Canada: Head Office, Montreal; Branch Offices, Toronto, Hamilton, Calgary, Vancouver

A complete line of equipment for Water, Sewage and Industrial Waste Treatment as well as Biofiltration Systems for Purification of Sewage and Concentrated Organic Wastes: Bar Screens, Grit Washers (patented), Grit and Sludge Collectors (patented), FLOCTROLS (R) (slow-mixing equipment) (patented), Sludge Elevators, Screenings and Garbage Grinders (patented), Conveyors, Chains, and Bearings.

View at right shows a 16 MGD Water Treatment Plant, Indianapolis Water Company, Indianapolis, Ind., which is completely equipped with Jeffrey Floctrols and Sludge Collectors.

View at left shows two Jeffrey FLOCTROLS (R) in Water Treatment Plant at Fairmont, West Virginia.

The Jeffrey Manufacturing Company of Columbus, Ohio, is prepared to grant licenses to all ultimate consumers for a reasonable royalty obtainable upon application, under any or all of its following patents: 1,999,863 — 2,102,990 — 2,160,534 — 2,237,172 — 2,266,097 — 2,268,461 — 2,291,121 — 2,291,641 — 2,324,637.



Jeffrey Mechanically Cleaned Bar Screen

View at left shows a Jeffrey back-cleaned type of screen at the Dayton, Ohio, Sewage Treatment Plant.

Based on a new principle of design this type of Jeffrey Mechanically Cleaned Coarse Bar Screen is practically fool-proof.

Screen Bars may be of Round or Rectangular cross-section.

Operation by time control is recommended but also can be by differential float. Provision is made for continuous operation if desired.

Jeffrey **JIGRIT** Washer

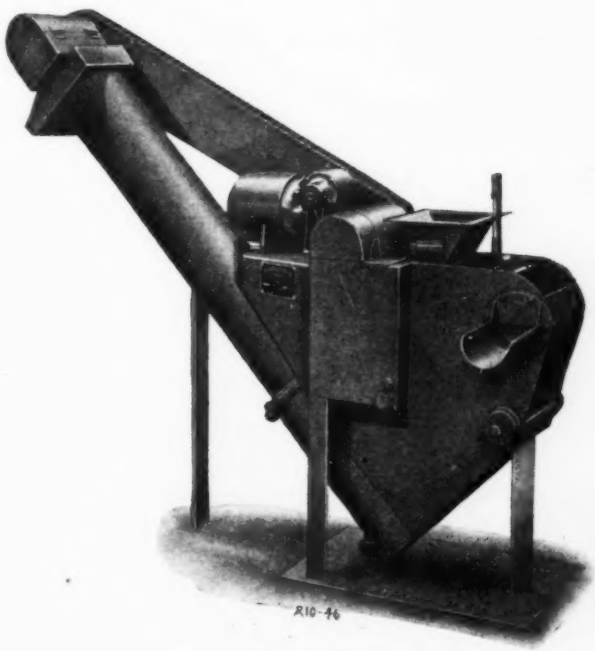
(REG. U. S. PAT. OFFICE)

Jeffrey patented JIGRIT Washer is now built in three sizes ranging in capacity from one ton to fourteen tons per hour, offering these advantages:

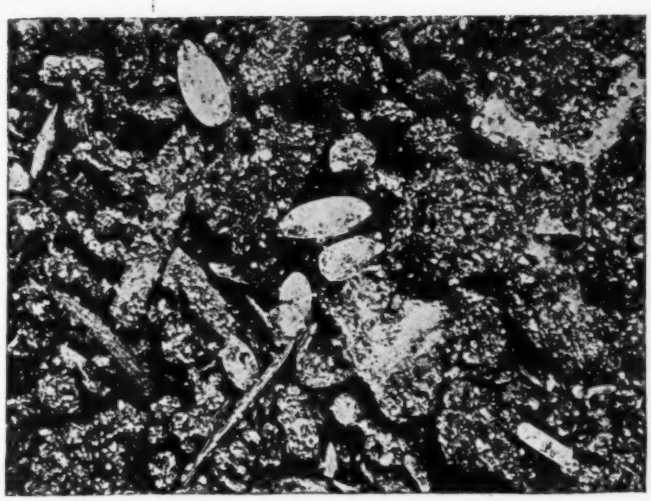
1—Removes 90% of putrescible solids.

2—Washed grit contains no organic seeds or unsightly material—can be used as fill without creating a nuisance.

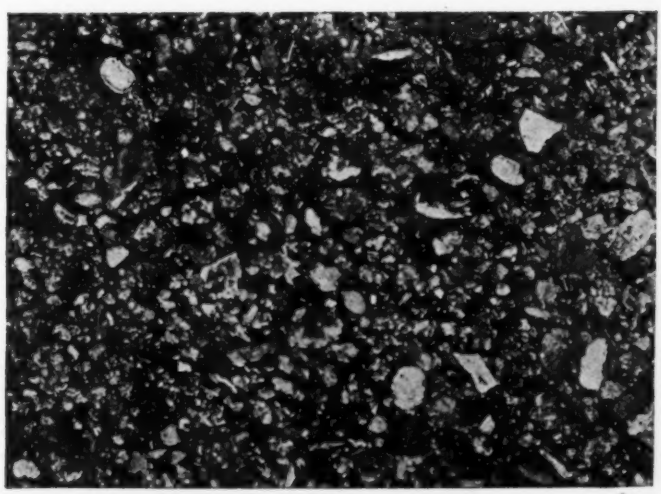
3—Recovers practically all of the +65 mesh grit.



Jeffrey No. 1 JIGRIT Washer



Magnified view of unwashed sewage grit

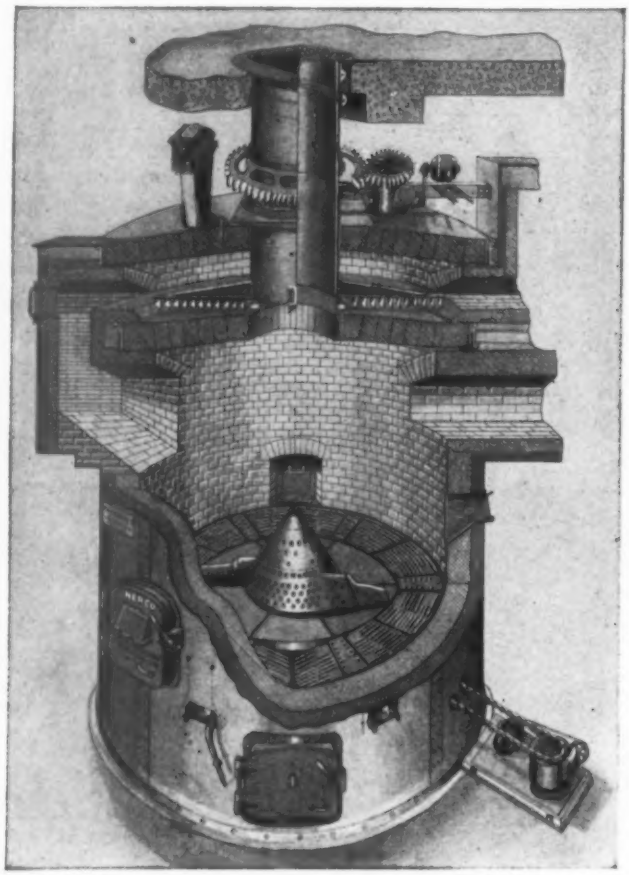


Magnified view of washed grit after passing through Jeffrey JIGRIT Washer

Small Towns!

THE NICHOLS DUOHEARTH DRYER-INCINERATOR

ONE UNIT — ONE OPERATION
Sewage Sludge AND Refuse Disposal
AT
LOWEST POSSIBLE COST



INTERIOR VIEW

Write today for Bulletin No. 216. Our Engineers are always available for consultation and engineering advice—without obligation.

Designed and developed by Nichols and first installed in 1945, the DUOHEARTH is a combination dryer-incinerator which dries and burns Sewage Sludge as well as Refuse in one operation. It is the result of a prolonged and serious effort to develop a unit, the installation and operating costs of which would be within the budget ability of the Small Town.

The DUOHEARTH is equally well suited to the needs of Industrial Plants, Factories and Utilities. It has demonstrated its ability, in full scale regular daily service, to reduce to a clean ash an extremely wide variety of industrial wastes, including wet sludges, screenings, crates, cartons, waste paper, manures and many others.

The upper hearth may be designed so that wet materials having a commercial value may be discharged and retained after drying, rather than being incinerated together with the waste materials in the lower chamber. This feature may be applied to the drying of sewage sludge as well as materials used in industry. Many such opportunities exist to turn the disposal of troublesome wastes into a profitable operation.

PRINCIPLE OF OPERATION

In the Duohearth Dryer-Incinerator are incorporated an upper hearth for drying wet materials and a Monohearth unit for burning trash, etc.

Wet material enters through an opening in the roof onto the upper hearth and is rabbled around and across the hearth by means of teeth, set at an angle, on arms attached to the revolving central shaft. After drying, the material may be withdrawn through an opening in the furnace wall or charged directly into the Monohearth unit for incineration. Heat for drying is supplied to the upper hearth from the Monohearth unit.

Trash, etc., enters through an opening in the roof direct to the Monohearth unit. This is equipped with a perforated metal cone fitted with tangential arms, rotating in the bed of burning refuse, constantly agitating the entire mass. Air, forced through the cone in the core of the burning refuse, assures rapid and complete incineration. Ash may be dumped into skids or trucks or removed by any other suitable method.

NICHOLS ENGINEERING & RESEARCH CORP.
60 WALL TOWER
NEW YORK 5 NEW YORK
UNIVERSITY TOWER BUILDING, MONTREAL, CAN.

SLUDGE INCINERATION

A Review of Modern Developments and the Status of the Practice

By E. T. KILLAM

Consulting Engr., New York, N. Y.

Developments in treatment plant equipment during recent years have demonstrated the feasibility of treating sewage essentially without nuisance—in, or adjacent to, closely built up areas. The economic advantages of elimination of long interceptors, and the prevention of deterioration of sewage quality prior to treatment by reducing detention time in interceptors, frequently establishes the desirability of constructing plants relatively close to centers of population instead of at remote locations, essential with some of the older types of plants. The increased importance of satisfactory sludge handling under such conditions has, among other factors, stimulated interest in sludge destruction by burning.

Methods of Sludge Drying and Incineration

Methods of drying and incineration of sewage sludge may be summarized as follows:

(A) Drying (For Fertilizer)
- (1) Without Preliminary Dewatering
  - (a) By Spray Dryer, such as at Plainfield, N. J.
- (2) With Preliminary Dewatering on Sand Drying Beds
  - (a) By Rotary Dryers at Grand Rapids, Mich., and Dayton, Ohio
- (3) With Preliminary Dewatering on Vacuum Filters
  - (a) By Rotary Dryers at Milwaukee, Wis.; Pasadena, Calif.; Houston, Texas

(B) Complete Incineration
- (1) After Dewatering on Sand Beds
  - (a) By Incineration in garbage-rubbish type incinerator of conventional design, contemplated or tried at a few plants with no known case of routine operation
- (2) After Dewatering on Vacuum Filters
  - (a) By Multiple Hearth Type Units for drying and incineration in one-step
  - (b) By Flash Dryer and Pulverized Fuel Type Incinerators, including drying followed by optional incineration

(C) Complete Incineration of Screenings
- (1) After Partial Dewatering in Roll Press
  - (a) In Hand Stoked Modified Garbage and Rubbish Type Incinerators, at Los Angeles "Hyperion" plant since 1934, and at Westchester County Sanitary District Plants since 1930
- (2) After Partial Dewatering in Centrifugal Machines
  - (a) At Milwaukee in hand stoked modified garbage and rubbish type incinerators
  - (b) At Milwaukee and Niagara Falls in multiple hearth type mechanically stoked—since 1937.

In addition to the foregoing applications of drying and incineration of sewage sludge and screenings, equipment now available offers a variety of special combinations deserving consideration in certain cases, and depending upon local conditions. Of particular interest are the possibilities in the combined disposal by incineration of garbage, rubbish, and sewage solids.

It is well recognized that the properly designed and well operated garbage and rubbish incinerator of today, will, under normal conditions, produce a substantial volume of excess heat.

There are notable examples of effective utilization of waste heat from garbage incineration in producing steam and power. The production of power, however, creates certain demands which must be considered in design and operation, and economical power production will for some time be limited to plants of substantial size.

An alternate use of such excess heat from garbage incineration (namely, as a means to drive off sufficient moisture from the sewage solids to make the sludge combustible without purchased auxiliary fuel) affords an interesting application of combined disposal.

Incineration and drying of sewage solids has doubtless been retarded due to the recognized item of operating cost, for driving off the moisture in the upper range of moisture content. If heat which would otherwise go up the incinerator stack may be utilized for this purpose, a consequent substantial reduction in operating cost is effected. This saving, combined with other obvious advantages, in many locations, of constructing the sewage disposal and garbage incineration plants at a common site, should make combined wastes incineration worthy of consideration in numerous instances, and the scope of applicability of incineration of sludge will, thereby, be substantially widened.

Inasmuch as the recent installations have been of the multiple hearth type, or the flash dryer and incineration type, these methods will be further discussed in brief.

Multiple Hearth Type Incineration

In 1934 the multiple hearth type incinerator, developed in the mining industry for roasting copper ore, was first applied to the incineration of sewage sludge at Dearborn, Michigan. In this, as in later installations, sludge is partially dewatered on vacuum filters prior to incineration.

The multiple hearth incinerator consists of a refractory lined circular steel jacketed unit, with as many hearths as may be indicated for the specific installation. Rotating plows on each hearth, driven by a vertical hollow air-cooled central shaft, constantly agitate and plow the material during drying and burning. The material drops through staggered openings in each hearth, to the next hearth below, being finally discharged from the bottom hearth in the form of an inert ash.

Multiple hearth installations normally include a blower for producing a supply of cooling air for the hollow shaft and revolving arms, a motor for driving the rabble arms, a rotating motor driven feeder, oil burner installation, and temperature control equipment.

In several cases preheaters have been included in the layout. The economic justification for a preheater, by means of which waste gases are utilized to heat the air supply to approximately 900 degrees F., depends upon the plant size, contemplated daily duration of operating period, and character and moisture of sludge to be burned.

The planned range of temperature at the furnace exit is approximately 1100 to 1300 degrees F. under normal optimum operating conditions.

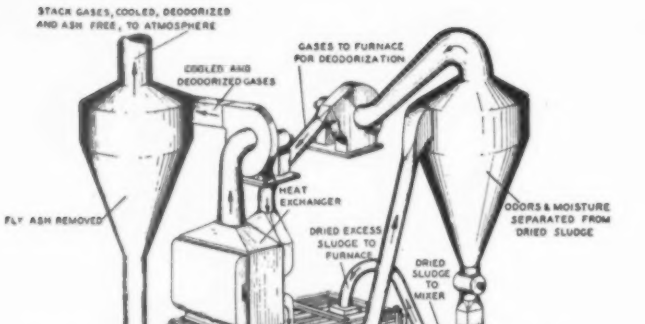
Beginning with the notable pioneering installation at Dearborn, Michigan, in 1934, numerous installations of the multiple hearth type incinerator have been undertaken. Recent reports indicate that equipment of this type has been, or is being installed, in 21 or more plants at this writing.

Installations at various plants to date vary in size from a single 9 ft. 3 in. diameter unit of four hearths, to the largest installation at Detroit, where four 22 ft. 3 in. diameter, 12-hearth units have been installed. It thus appears that America's largest Multiple Hearth Furnace installation is approximately seventy times the size of the smallest installation.

The original Dearborn incinerator handles mixed raw chemical and digested Imhoff sludge, the quality of which is indicated by the fact that the long term average volatile content of the cake fed to the incinerator was 46.6 per cent.

Subsequent installations have been in plants which will produce sludge of widely varying characteristics, including the following:
- (a) Raw Primary
- (b) Raw Chemical
- (c) Digested Primary
- (d) Raw Activated
- (e) Digested Activated

Several units have been purchased for incineration of fine screenings and 5 units have been installed with the expressed intention of handling ground garbage along with the sludge.


STACK GASES, COOLED, DEODORIZED AND ASH FREE, TO ATMOSPHERE
GASES TO FURNACE FOR DEODORIZATION
COOLED AND DEODORIZED GASES
HEAT EXCHANGER
FLY ASH REMOVED
DRIED EXCESS SLUDGE TO FURNACE
ODORS & MOISTURE SEPARATED FROM DRIED SLUDGE
DRIED SLUDGE TO MIXER
FURNACE FOR DEODORIZING GASES AND BURNING EXCESS SLUDGE
BY-PASS DEODORIZED & DRIED SLUDGE MAY BE DIVERTED FOR USE AS FERTILIZER
HOT GASES
FLY ASH AND ASH FROM FURNACE PIT REMOVED
WET & DRY SLUDGE MIXER
WET SLUDGE FILTER CAKE
FLASH DRYER

The C. E. Raymond System of Flash Drying and Incineration. (This System Makes Permissible Complete Sludge Incineration or a Partial Diversion for Use as Fertilizer. Another Illustration Shows the Cyclone End of the Raymond System in Service.)

Flash Drying and Incineration

Flash drying and incineration of sewage sludge was first undertaken on a large scale at the West Side Plant of The Chicago Sanitary District in 1933.

This type of equipment involves incineration in two stages—or in other words the drying of the solids to approximately 10 per cent moisture, followed by incineration of the dried material.

The filter cake, with a normal moisture of 75 to 85 per cent, is mechanically mixed with sufficient dried material to develop proper consistency for drying in the flash dryer. Hot gases and this mixture drop into the flash dryer, are violently agitated, and the dried material and vapors are discharged into a cyclone collector. The dried material—approximately 10 per cent moisture—is mechanically divided, a portion being returned to the mixer for blending with the wet filter cake. The balance, or excess, is sent to storage for fertilizer or to a pulverized fuel type of incinerator for destruction, as the case demands. The vent vapors are likewise discharged to the incinerator.

The average design temperature in the dryer is 1100 to 1300 deg. F., and the temperature of the vent vapors varies from approximately 200 to 300 degrees.

The initial installation—at Chicago's West Side Plant, was designed to dry and incinerate raw activated sludge filter cake at 80 to 85 per cent moisture. The rated capacity is 2,000 pounds net dry solids per hour or 8,000 pounds of water evaporation per hour.

Basing the design upon the performance of this unit, equipment was installed at the Calumet Plant of the Chicago Sanitary District and placed in operation in 1935. Three units—each with a capacity of 6,000 pounds net dry solids per hour, or 24,000 pounds of water evaporation per hour, were included. The sludge handled consisted of raw activated filter cake—with small amounts of grit and heavy primary solids from 20 minute detention primary tanks.

In November, 1937, this same type of equipment was placed in service at Neenah-Menasha, Wisconsin, with a capacity of 0.75 tons dry solids per hour, or 3,500 pounds of water evaporation per hour. The sludge at this plant will at times be digested—primary sludge, and at other times will be chemical sludge. A large proportion of paper mill wastes—with high clay content, has at times developed sludge as low as 35 per cent in volatile content.

Similar equipment is now being installed at Buffalo, New York, for incineration of partially digested primary sludge. This plant includes three units each, with a capacity of 5,000 pounds per hour evaporation.

The largest installation of flash drying equipment is in Chicago's notable South West Activated Sludge Plant, where four units—each served by two drying units, with the latter having an evaporation capacity of 20,000 pounds each per hour, are being installed. In this installation power will be generated from combustion of the pulverant dried sludge, with the assistance of auxiliary powdered coal. In this single plant with a total evaporation capacity of 40 tons per hour, combustion engineering has attained a real goal in sewerage practice in America.

The first installation under contract locally, is at Tenafly, N. J., where a small single unit of the drying apparatus, with an evaporation capacity of approximately 0.35 tons per hour, is to be installed, for drying raw activated sludge filter cake and fine screenings, preparatory to the burning of the dried material with garbage and rubbish in open hearth incinerator of conventional design.

Summary

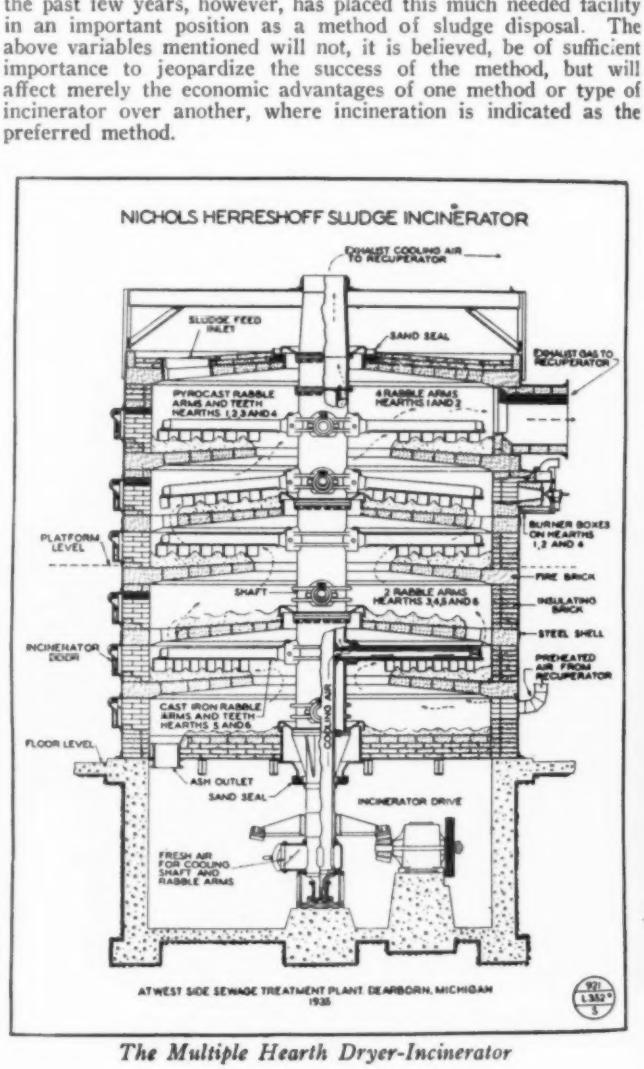
In summary, sludge disposal by drying or incineration has constituted one of the most active phases of development, in the past few years, in the field of sewage treatment.

While operating data and operating costs for a variety of installations will soon be available, it can be safely stated that careful consideration of the local conditions in each municipality will be necessary in order to approach the most economical solution of the problem.

The variables affecting alternate methods of sludge disposal vary no less than the wide range of requirements for degree of sewage treatment. In this way, it would appear that a careful analysis of the problem prior to final selection of the method of sludge disposal, will necessitate thorough consideration of the variables involved.

The characteristics of the sludge and moisture and combustibles content vary widely, depending upon the type of treatment from which the sludge originates. The volatile content of various sludges may vary to as wide a range as from 30 per cent of the total dry solids, to 80 per cent, or even higher. While a heat value of 10,000 B.t.u. per pound of dry volatile matter has frequently been used in computation, additional experience indicates wide variations in B.t.u. content per pound of combustibles.

The demonstrated performance in sludge incineration during the past few years, however, has placed this much needed facility in an important position as a method of sludge disposal. The above variables mentioned will not, it is believed, be of sufficient importance to jeopardize the success of the method, but will affect merely the economic advantages of one method or type of incinerator over another, where incineration is indicated as the preferred method.


NICHOLS HERRESHOFF SLUDGE INCINERATOR
EXHAUST COOLING AIR TO RECUPERATOR
SLUDGE FEED INLET
SAND SEAL
EXHAUST GAS TO RECUPERATOR
PYROCAST RABBLE ARMS AND TEETH HEARTHS 1,2,3 AND 4
4 RABBLE ARMS HEARTHS 1 AND 2
PLATFORM LEVEL
BURNER BOXES ON HEARTHS 1,3 AND 4
FIRE BRICK
SHAFT
2 RABBLE ARMS HEARTHS 3,4,5 AND 6
INSULATING BRICK
STEEL SHELL
INCINERATOR DOOR
PREHEATED AIR FROM RECUPERATOR
COOLING AIR
CAST IRON RABBLE ARMS AND TEETH HEARTHS 5 AND 6
FLOOR LEVEL
ASH OUTLET
SAND SEAL
INCINERATOR DRIVE
FRESH AIR FOR COOLING SHAFT AND RABBLE ARMS
AT WEST SIDE SEWAGE TREATMENT PLANT DEARBORN, MICHIGAN 1935

The Multiple Hearth Dryer-Incinerator

REDUCING COST OF SLUDGE REMOVAL

Experiences at Aurora, Ill., with a "Saddle-Bag" Tractor

By WALTER A. SPERRY, Superintendent
The Aurora Sanitary District,
Aurora, Illinois

DURING the summer of 1940 the Aurora Sanitary District constructed eight new sludge drying beds under a W. P. A. contract. This increased the sludge drying area from 50,000 to 96,250 square feet, which gave 1.44 square feet per capita on the original design basis of 67,000 population and 1.96 square feet per capita on the basis of the present population of 49,000. This increase was desirable due to the frequency of winter cleans caused by increased loadings on the plant and the addition of secondary sludge to the digesters in 1937.

Sludge Removal Methods Evaluated

New drying bed construction involved the selection of a method for removing sludge. Two factors entered in. The first was the cost of trackage versus a more modern method of mechanical removal. The second revolved around the sponsor's credit in the W. P. A. set-up for the disposal of some 3,500 cubic yards of excavation. If contractor's equipment was hired to do this work it would cost more than if the sponsor had in hand dirt moving machinery where the only expense would be gasoline, motor oil and the operator's wages. This led to the consideration of abandoning tracks in all beds and substituting therefor the "saddle-bag" tractor originally planned by Mr. W. B. Walraven of Springfield, Ill., and described by him in an article, "A New Device for Handling Dried Sludge," in *Water Works and Sewerage* of February, 1934. General investigation indicated that this was, by far, the best device available. Some pressure was brought to bear to adopt a self-propelling bucket elevator to pick the sludge from the beds and discharge it to a following truck. Also it was urged to purchase a tractor with a yard shovel attachment in front, similarly working with a truck.

These devices were not suitable, first, because of the damage to the sludge beds in attempting to pick up mechanically a thin layer of material from a relatively thin layer of sand without disturbing the gravel underneath; second, because of the bulk of the equipment and the cutting up of the bed by both the tractor and truck; third, a truck was not suited to travel over the sludge storage pile; fourth, all of these devices were expensive and of no value for any work about the plant; and fifth, the required space for storage in the interim period was not available.

Advantages of the Crawling Tractor

The Springfield tractor, on the other hand, was self-contained. Equipped with caterpillar treads enabled it to travel over the sludge storage pile under quite adverse conditions, i.e., when wet and soft.

Due to its ability to mount and crawl over the storage pile, the "saddle-bag" tractor appeared to be especially useful in making the most of limited storage areas. It has also proved useful for the disposal of grit from the screen house to the storage space. The machine can be equipped with a bull-dozer for snow problems in the winter, for trimming the sludge pile and for grading gravel roads or pulling stumps. The tractor required small storage space and has generally offered all the facilities of a man carrying two buckets where the load could be transported and deposited anywhere the feet could walk.

Considering its adaptability and general usefulness, it seems surprising that but three of these machines are in use to date. The original one is at Springfield, the second at Mansfield, Ohio, and the third here at Aurora, Ill.

Trackage for the new beds would have cost in the neighborhood of three thousand dollars ($3,000). The tractor equipped with the side bins cost two thousand, two hundred and sixty dollars ($2,260). Against this cost its temporary use as a construction unit in building the sludge drying beds saved the Aurora Sanitary District about sixteen hundred dollars ($1,600) over rented equipment for the construction period.

The Unit

The tractor (see cut) is an "M" type Allis-Chalmers caterpillar type machine. It is driven by a 32.4 H.P. engine with four forward speeds, is equipped with starter, and weighs 6,500

The Tractor Being Loaded During a Winter Cleaning Operation
The hard, frozen sludge is first broken up by the "breaking gang," and thereafter easily loaded into the "saddle bags." Note the comfortable loading height of these side-bins.

pounds. Equipped with the bins, it is about 8 feet long, 7 feet wide and 6 feet high over-all. The bins, which have a combined capacity of 3 cubic yards, add another 1,500 pounds for a total weight of 8,000 pounds. It has a bearing of 1,530 square inches. With full bins this gives a pressure per square inch of from 7 to 9.5 pounds, depending upon the moisture content of the sludge. The bins are constructed of 8 gauge metal and the whole device is of such strong and sturdy construction that its life will be many years. The original machine purchased in 1932-33 is still in use at Springfield and in good order.

Performance Records

Before purchase of the tractor, in the period July, 1939, to May, 1940, inclusive, 4,055 cubic yards of sludge were removed from the Aurora beds to the storage pile at a total cost of $2,095.51, or 51.6c per cubic yard. The unit cost varied from 30.6c to 67.7c per cubic yard, as between summer and winter conditions. For this period the standard crew then hired for the cleaning jobs consisted of a team at $10 per day and seven men at 45c per hour. This gave us a daily hired labor cost of $35.20. Experience showed that three 1 cubic yard cars, two men to a car, gave the right balance of work for the team and Fresno scraper used.

The tractor was purchased and went into use in June, 1940. Between June, 1940, and March, 1941, inclusive, 4,933 cubic yards of sludge were removed to the pile at a total cost of $1,057.59, or 21.4c per cubic yard, to which should be added two cents per cubic yard for tractor oil and gasoline. The tractor crew consisted of four men at 45c per hour, or a total cost of $14.40 per day. This is a difference of $20.80 per day for hired labor between the two methods. Note that the gang foreman in the first case is the tractor operator in the second case. He is a plant employe on the regular payroll and not included in either cost estimate. This indicates a saving of 54.8 per cent for the new method.

At the time the tractor was purchased it was assumed that the saving would be in the cost of the track and the reduced price due to the temporary rental to the Government, and that the time of sludge removal might be extended since but four men were lifting sludge against six with the old method. The interesting surprise was that four men and the tractor do at least 90 per cent as much work as six men, due to the fact that the trip to the storage pile is but once for every 3 cubic yards, whereas, formerly each 1 cubic yard lot was pushed by car to the pile by its two man crew, with "waits" for any car ahead to clear switches.

During interim periods the tractor is stored in the screen house and is used almost daily to remove grit. A bull-dozer blade is being planned for permanent mounting for clearing snow from the plant driveways, trimming the storage pile, and for maintenance of the gravel roadways.

Two Minor Objections Appear

Two minor objections to the tractor are that a little more care must be taken to keep the sludge beds well sanded against the disturbing effect of the tractor cleats. The second objection developed this winter when it was discovered that the physical condition of the operator was affected due to shock and jar caused by the frozen state of the ground. Happily this was satisfactorily corrected by the purchase and use of a wide leather belt such as is used by motorcyclists and truck drivers to support the abdominal region.

INSTRUCTIVE WALL PANEL FOR TREATMENT PLANTS

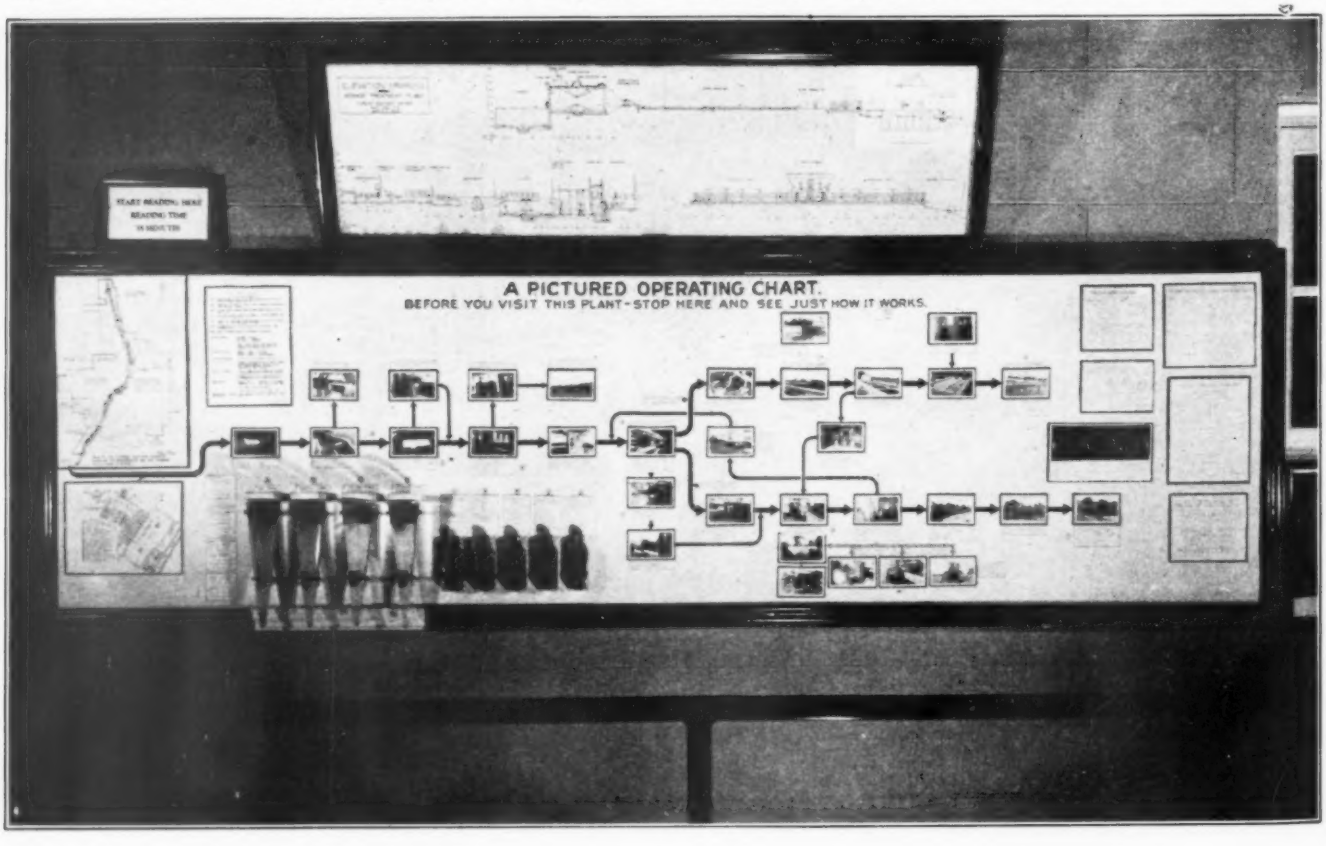
A Picturized Operating Chart with Specimens Attached

AT the Sewage Treatment Plant at Aurora, Illinois, the visitor runs smack into this wall panel designed by Walter A. Sperry, Plant Supt.

The sign reads—"Before inspecting the plant stop here long enough to see how it works. But 15 minutes is required to read all captions."

We are reproducing this picture of Aurora's instructive chart because it seems an ideal method of giving the visitor a preview of what he is to see in looking over the works. Further than that, it is used frequently for the purpose of instructing school classes, Boy Scouts and Girl Scouts who visit the plant.

Photographs are used to show the relationships of each plant unit to the other and its functions are indicated by live specimens of crude, settled, filter effluent and final plant discharge in Imhoff Cones. Samples of sludge "before and after" are exhibited and also petri dishes showing what happens to the bacteria. The whole thing is a great idea and, what's more, saves many words.



SLUDGE AS FERTILIZER

Its Place and Use in Vegetable Gardening

By LE ROY W. VAN KLEECK
Senior Sanitary Engineer
Connecticut State Dept. of Health, Hartford, Conn.

BECAUSE the war made it imperative that full use be made of all of our natural resources, the State Department of Health of Connecticut discussed the use of sewage sludge for fertilizing lawns, flower gardens and food crops.

Only Digested Sludge Recommended

When raw sewage solids are settled in tanks at sewage plants and stored under controlled conditions in special tanks called "digesters" (either heated or unheated) for considerable periods, it is called digested. The digestion of sludge involves a biochemical process in which the organic matter remaining in the sludge is in a more stable form. Whereas raw sludge is generally brown in color, lumpy, watery, and has an offensive odor, digested sludge is black in color, homogeneous, has the consistency of thinned molasses, and gives off a tarry or gassy odor which is not offensive. Raw sludge is odorous, has a high grease content, tends to make soils acid, is a potential carrier of pathogenic bacteria, and is not humified for soil use. The use of raw sludge in any form is not recommended.

Liquid digested sludge contains from 85 to 98 per cent water and is rarely used as a fertilizer. Principal objections are, first, the large quantity of fluid bulk that must be transported; secondly, the difficulties of application to the area to be fertilized; and, thirdly, the greater likelihood of objectionable odor. Instead, sludge is generally utilized following partial dewatering by draining it on beds of sand, pressing, centrifuging or vacuum filtration. The partially dried sludge is then referred to as "sludge cake," and ordinarily contains 70 per cent or less of moisture. Such cake is dry enough to be shoveled and spread like manure or moist soil.

Fertilizing Value of Digested Sewage Sludge

A comparison based on chemical analysis of digested primary sludge and related materials as reported by various investigators is afforded in the accompanying table.

TYPICAL CHEMICAL ANALYSES OF SEWAGE SLUDGE, MANURES, AND COMMERCIAL FERTILIZERS

	Total Nitrogen % (Dry Basis)	Total Phosphoric Acid % (Dry Basis)	Total Potash % (Dry Basis)
Digested Sludge (Average of samples from a number of sewage plants in Connecticut)	1.7	1.5	0.15
Horse Manure	2.2	1.10	1.6
Sheep Manure	1.8	1.52	3.0
Poultry Manure	3.6	3.5	1.9
Common Garden Commercial Fertilizer	4.0	9.0	10.0

It will be noted that digested sewage sludge compares favorably with the ordinary run of manures. Its principal deficiency is in potash. The nitrogen in sludge has been shown to be available over a long period (generally at least two years) and there is, therefore, no danger of so-called burning of crops.

The chemical analysis of sludge does not, however, tell the entire story. Primary digested sludge has its greatest use as a soil conditioner, constituting as it does a valuable source of humus. Generally, about 50 per cent of the dry weight of sludge is humus. Sludge is not a complete food for plants as commercial fertilizers are and cannot be expected to serve as an all-purpose plant food. It should be supplemented by the use of commercial fertilizers. Its application, however, has a favorable effect on soil structure. Soils repeatedly planted to growing crops require the organic humus present in manures, peat moss, green cover crops, and sludges. In addition sludge contains soil improving and growth promoting values by replenishment of organic matter and because the minor elements it contains are needed by plants.

Another significant point, not revealed in the chemical analysis of digested sludges, is the comparative freedom of such sludges from weed seeds which are largely destroyed in the digestion process. On the other hand, most manures, unless well rotted, contain numbers of weed seeds which prove very objectionable, particularly when they are spread on lawns. Tomato seeds and a few of the cucurbits will sprout in sludge, but they are not ordinarily troublesome.

When used continuously on land, sludge not conditioned with lime tends to acidify the soil. Hence, corrective measures must be taken every three or four years to avoid damage to plants requiring a neutral or near neutral soil by checking acidity, caused largely by the breakdown of the greases and fats present in sludge. Judicious applications of ground limestone or hydrated lime will correct such acidity.

Methods of Applying Digested Sludge and Hygienic Considerations

Sludge may be applied as a top dressing in the case of trees or lawns; in the hill in the case of melons, squash, or other vine crops; or spread, then plowed or spaded into the soil. When used as a top dressing, it should not be applied too thickly, especially on lawns, or it may choke the growing vegetation. Recommended amounts are listed in an accompanying table. Sludge may be applied when the ground is frozen or covered with snow. In such cases it is raked and pulverized into the soil in the spring. Grinding sludge cake with machines greatly enhances its application as a top dressing. Except where applied to grass, trees, shrubs or perennial beds, sludge should be placed in the hill or plowed under in the fall or early spring before planting the crop.

Digester sludge is safe from the health standpoint if mixed with the soil and not applied to the growing crop. It is safer not to plant root crops eaten raw (examples, carrot or radish) or vegetables grown in close contact with the soil and eaten raw (examples, lettuce, celery, onions) in ground recently fertilized with sewage sludge.

The digestion of sludge, together with the commoner methods of de-watering such as air-drying or vacuum filtration (in which case most sludges are conditioned with lime, giving a high enough pH to kill great numbers of bacteria), afford sufficient protection against intestinal diseases. It is also desirable, of course, to use reasonable care in handling it. A special committee of the Federation of Sewage Works Associations reporting on the "Utilization of Sludge as a Fertilizer" states: "The committee knows of no case of sickness traceable to the use of digested sludge or activated sludge." (In the latter case the sludge has been subjected to heat drying which effects post irrigation along with the drying.)

Amount of Digested Sludge to Use

While an excess of sludge will rarely do harm, except in cases of outright mechanical smothering of growing things, the following suggestions for its application have been made by various investigators:

For orchards—16 tons sludge cake per acre (or about 11 cu. yds. per acre).

For grass—10-20 cu. yds. per acre (or 0.6 to 1¼ cu. ft. per 100 sq. ft. of soil).

For vegetables, shrubs and flowers—20-60 cu. yds. per acre (or 1¼ to 3¾ cu. ft. per 100 sq. ft. of soil).

Fortifying Digested Sludge

Fortifying sludge with chemicals will increase its total food constituents and hence its value. Such sludge should be applied in smaller amounts, depending on the type of crop and the local soil conditions. We understand from commercial fertilizer distributors that a 3-8-7 formula will be available for home gardeners this year instead of a 5-8-7 formula ordinarily recommended for general use. This means a cut of 2 per cent in the total nitrogen. If the new formula is mixed in equal proportions with sludge (on a dry basis), it will result in a 2.4-4.8-3.6 mixture. Or the following formula can be used, this being suitable for general use on almost any crop or soil:

Digested sludge (dry basis)*	400 lbs.
Ammonium sulphate†	60 lbs.
Acid phosphate (20%)	100 lbs.
Muriate of potash	40 lbs.

*400 lbs. of bone dry sludge amounts to about ½ ton of sludge cake as removed from the average sand drying bed or 1,300 lbs. of cake as removed from the average vacuum filter. Roughly ¾ of a cu. yd. or about 20 cu. ft. Other formulae may be used for special cases or a particular soil.

†May not be available this year because of war conditions.

Use of Sludge as Fertilizer

Some of the uses of sludge have already been pointed out. It is particularly adapted to lawns. Sludge deepens the green color of grass and stimulates a luxurious growth. Its benefits seem noticeable for several years. It should be applied in the amounts given above late in March and again early in September.

The home owner may well use it for the flower garden. Here it provides a much needed humus for the hot summer months as well as supplying a moderate but long-yielding amount of nitrogen.

Its use is also indicated for trees and shrubs. Trees fertilized with sludge frequently have a healthier foliage, both in amount and color, and retain their leaves for a longer time in the fall than nearby unfertilized trees.

In the vegetable garden its uses have already been suggested. It has been found to be particularly beneficial for corn, potatoes, beans, spinach, asparagus, and all vine crops. With the scarcity of animal manure, the victory gardener might well turn to sludge for his humus needs, bearing in mind the safeguards discussed above. The cost of manure in his community may be used as a rough index of the value of local sludge. A charge of from 25 cents to $2 per cubic yard for unground sludge is frequently made at sewage plants. Sludge may be transported in truck bodies or bagged for hauling in smaller amounts by private car.

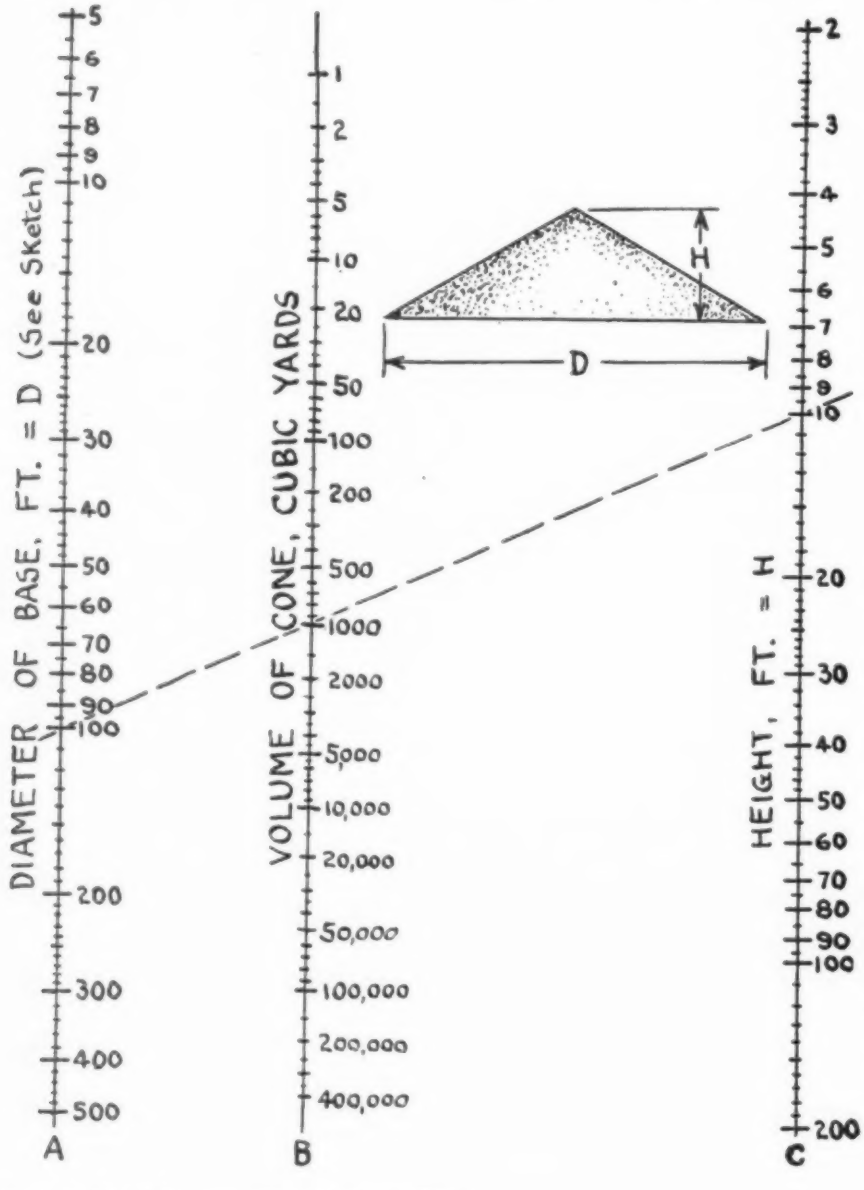
Why Digested Sludge Has Not Been More Widely Used as a Soil Conditioner

What are some of the reasons why digested sludge has not been used more extensively as a soil conditioner? Undoubtedly an aesthetic dislike to its use because of its origin and source, and the fear of producing offensive odors, are paramount in the minds of many laymen and agriculturists. Since properly digested and dried sludge, and heat-dried and ground raw activated sludge have been established as safe hygienically for application to the soil, there appears little room for argument from the health standpoint against use of such sludges. With regard to odor, many of the more common animal manures, including cow, pig and poultry wastes, have as much or more odor than sludge, especially if applied before they are thoroughly rotted or composted.

Another reason why sludge is not used is the lack of promotion of its use. In some cases this is no fault of the plant operating personnel, but is caused by a lack of time. The primary job of sewage treatment plant personnel is the protection of the public health and the prevention of nuisance from raw sewage, and not the manufacture or sale of fertilizer. Sludge disposal as fertilizer, when it involves salesmanship, storage facilities, grinding equipment, and in some cases bagging facilities, delivery and bookkeeping, is beyond the scope of many of the smaller treatment plants.

An objection to the use of sludge as a fertilizer is the lumpy or chunky physical form of much sludge cake, which makes it unsatisfactory for lawns, shrubs, and flower beds. Heat-drying or air drying and grinding produces a product much more suitable for general use.

For a complete discussion of Sludge as Fertilizer the reader is referred to the Fed. Sew. Wks. Assn. Manual of Practice No. 2.



CONTENTS OF CONICAL PILES*

Frequently it becomes desirable or necessary to estimate yardage in a pile of dirt, sand, stone, gravel, coal, etc.

Without any figuring whatever the accompanying chart quickly gives the number of cubic yards in any conical pile.

For example, how many cubic yards in a conical pile whose based diameter is 100 ft. and whose height is 10 ft.?

The dotted line drawn across the chart shows how it is done. Run the line through the 100 ft. diameter, column A, and the 10 ft. height, Column C, and the intersection with column B gives the answer as a little less than 1000 cubic yards.

The range of the chart takes care of all diameters from 5 to 500 ft. and all heights from 2 to 200 ft. However, in the event that diameters or heights should be greater or less the same chart is still applicable. Thus if the diameter should be 1000 ft. instead of 100 ft. and if the height should be 100 ft. instead of 10 ft., the same dotted line would solve the problem excepting that the answer would be 1,000,000 cubic yards instead of 1000 cubic yards. In that case the rule is this: For every cipher added to column A, add two ciphers to the answer in column B, and for every cipher added to column C, add one cipher to the answer in column B. This means that when the problem is 1000 ft. diameter and 100 ft. height, three ciphers must be added to the result in column B.

*Contributed by W. F. Schaphorst, M.E.

SLUDGE LAGOONING

By DON E. BLOODGOOD
Assoc. Prof. of Sanitary Engineering, Purdue University

THE deep-pit sludge digestion at Indianapolis was first reported on by Calvert in 1928.[1] This method of sludge digestion had then been in use for two years. At the outset, Indianapolis expected to use "sludge lagoons" or "deep-pit sludge digestion" only as a temporary measure until some other process could be decided upon. The pilot plant tests on fertilizer production in 1931 indicated quite conclusively that this means of sludge disposal was not sufficiently lucrative to warrant competition with Milwaukee, Houston and Pasadena in their sludge marketing enterprises.

The Indianapolis sludge lagoons met the needs for sludge disposal inasmuch as it was possible to handle all sludge produced at the Indianapolis treatment works without odor or other nuisance. There being ample area for additional deep lagoon construction, and because lagoons could be built at a relatively small cost, it seemed advisable to continue this method of handling sludge until a more suitable or economical process could be found.

Sludge lagoons have been used continuously at Indianapolis without creating nuisance for the past 20 years. It is believed that such sludge disposal economy has been the explanation, in a large part at least, for the low unit cost of sewage disposal.

Although sludge lagooning cannot be considered as a satisfactory method for sludge disposal for all installations, in many cases it can be used to meet emergencies which arise.

Sludge lagooning can be carried out successfully, but the operation must be as carefully supervised as any other part of the sewage treatment process. A sludge lagoon operated on the same basis as the old refuse dump will be just as unsatisfactory as these old dumps were, but if they are operated with common sense plus some pride the result will show as much improvement as the "sanitary fill" method of refuse disposal does over the old dump.

Locations of Lagoons

The lagoon area at Indianapolis is located in the flood plain between White River and Eagle Creek. Most of the lagoons have sand bottoms, as most of the top soil was used in constructing the levees forming the pits. The bottoms of the pits are only 6 to 8 feet above the ground water at minimum ground water elevations, and during flood stages the ground water is often above the pit bottoms. Although many of the lagoons have sand bottoms, there seems to be very little seepage into the ground once there is sufficient sludge in a lagoon to cover the bottom. In the early days numerous attempts were made to loosen or scarify the bottoms between cycles of operation so that the seepage would be increased. In later years, however, the amount of drainage through the bottom of the lagoon was thought to be only minor in nature. All excess water was either allowed to overflow at the top to adjacent pits or was removed with portable pumps when a lagoon was being dewatered.

Construction of Lagoons

In constructing the lagoons the top soil which could be reached with a 20-foot boom was removed with a clamshell bucket and caterpillar crane which piled it as a levee just wide enough at the top for a path. The levees were about 12 feet high and the natural slope assumed was about one foot vertical and one and one-half horizontal. In the early construction very little attention was given to leveling the bottom or even removing stumps of trees in some of the pits. In later years when the sludge was removed from some of these crudely constructed lagoons, considerable difficulty was encountered, so that when the WPA days came along a project was instigated for leveling the bottoms of the lagoons, removing stumps, and increasing the width of levees so that they could be used as roadways.

The smallest lagoon now in service is about 300x325 feet. The lagoon No. 8 on the map (Fig. 1) was originally three lagoons, but the north and south levees were removed to make the larger unit. Experience has shown that the area of a lagoon is not too important. The most desirable area for a single lagoon will depend upon the total amount of sludge to be disposed of at any particular plant.

In planning lagoons, where the sludge must eventually be removed, it is desirable to have the tops of the levees wide enough for truck traffic. Lagoons which must be emptied should be built with an earth ramp having a slope such that the available trucks will have no difficulty in climbing it with their maximum load. Some of the ramps at Indianapolis have at least 15 per cent grades. Cinder roadways are maintained on the bottoms of the lagoons as the sludge removal progresses.

TABLE I

Character of Sludges Pumped to Lagoons

	Primary Sludge — Per Cent			Activated Sludge — Per Cent			Plain Aeration Sludge — Per Cent		
	Solids	Volatile	Nitrogen as N	Solids	Volatile	Nitrogen as N	Solids	Volatile	Nitrogen as N
1935.....	4.42	78.7	2.82	2.78 0.41*	63.6	4.58	4.32	69.7	3.96
1936.....	4.84	74.8	2.88	2.78 0.64*	63.9	4.80	4.58	68.7	3.79
1937.....	4.25	71.1	2.48	1.69 1.04*	64.0	4.30	4.11	66.2	3.26
1938.....	5.15	72.4	2.47	2.58 1.08*	64.2	4.59	4.45	64.8	3.40
1939.....	5.84	68.4	2.58	0.89*	61.6	4.61	3.82	65.3	3.31
1940.....	5.83	62.1	2.45	0.79	60.2	4.45	3.53	62.7	3.76
1941.....	6.27	68.2	2.63	0.78*	63.5	4.39	3.54	65.5	3.44
1942.....	7.04	69.1	2.58	0.92*	66.0	4.72	4.44	65.0	2.99
Avg...	5.45	70.5	2.62	2.46 0.82*	63.5	4.56	4.10	66.0	3.49

*Concentration of return sludge. Some sludge was wasted at this concentration; the remainder was concentrated to the higher figure in a sludge concentration tank.

Sludge Distribution and Supernatant Drains

The sludge is distributed to the lagoons through steel pipes laid about three to four feet deep in the levees. From the plant to the lagoons the main piping is 12 inches in diameter. The distribution lines are 8 and 10 inches with gate valves on branches leading horizontally into each of the four corners of a lagoon wherever possible. Eighteen-inch tile is used for the valve boxes. There have been only a few instances where freezing caused any trouble

Starting a Lagoon
Discharge line extending into lagoon

Lagoon Partially Filled

Sludge Being Removed
Lagoon nearly clean

with valves set in these boxes. The discharge lines beyond the valves extend into the lagoons about 20 feet beyond the face of the levees. No particular attention has ever been given to the grades on which the pipelines have been laid, consequently draining of the lines taken out of use was not possible. Caking of sludge in the lines, when not in use, has never been a problem. Stoppages which have occurred have usually been removed by blowing compressed air through the lines containing sludge. Appreciable coatings of grease were found in some of the lines when skimmings from the primary tanks were being disposed of by pumping them to the lagoons. The skimmings caused no particular difficulty in the lagoons, however.

A large percentage of the distribution system has been made up of second-hand steel or wrought iron pipe and it has served very well. The most recent extension to the distribution system was made with a 10-inch, 3/16-inch wall, tar coated, steel pipe with plain ends and in 40-foot lengths. The lengths of this pipe were connected by electric welds and dropped into the trench after welding.

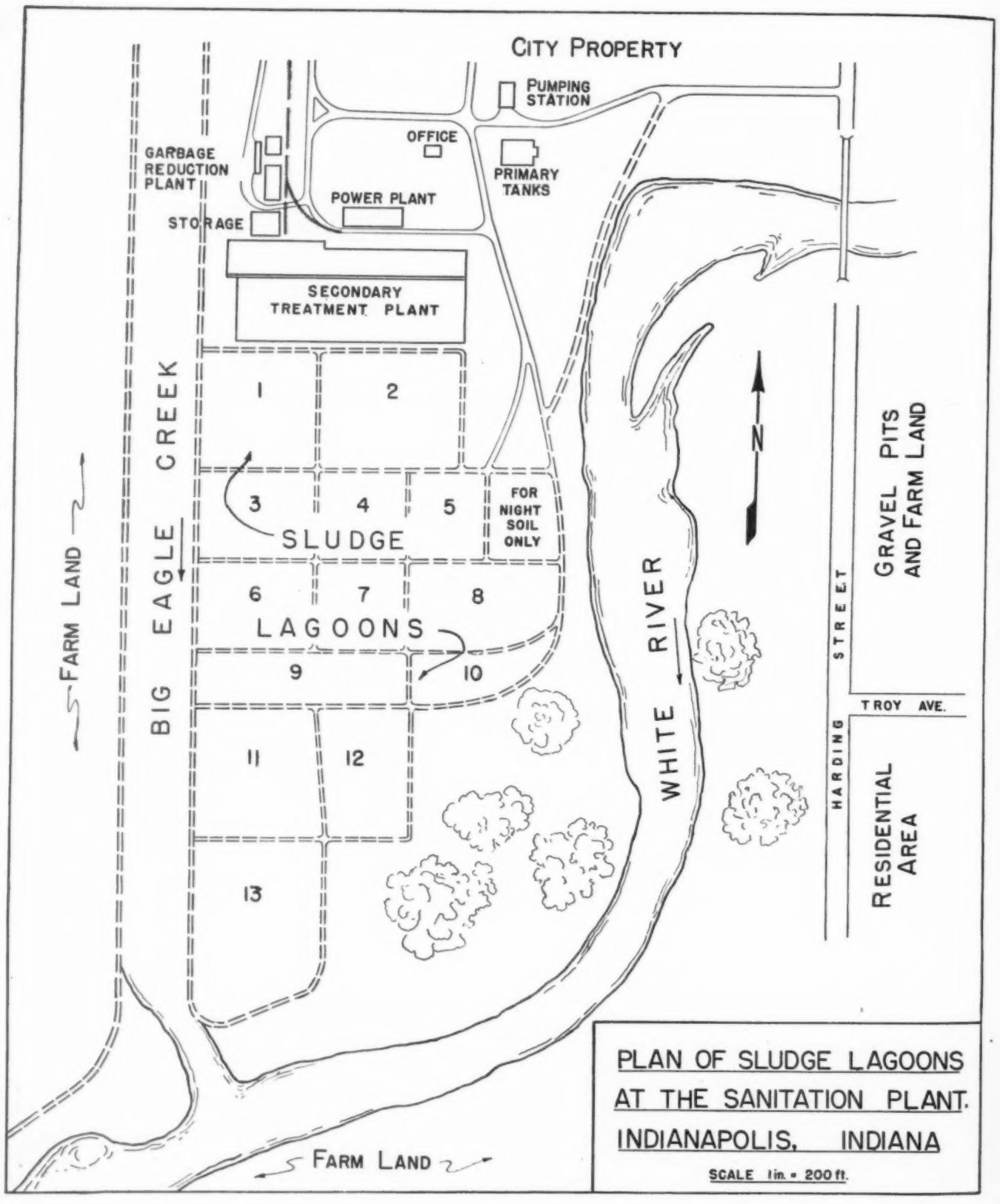


Fig. 1.—Plan of Sludge Lagoons at Indianapolis Sewage Treatment Plant.

No attempt has been made to return the supernatant to the sewage plant. Operation of the lagoons in recent years has shown that if the supernatant flows through several lagoons and finally into one containing practically no sludge, the overflow from this last lagoon will be entirely satisfactory for discharge into the receiving stream. Supernatant or sludge is drawn from one lagoon to another through pipes placed across the levees at about a depth of 3 feet. No valves are used on these lines. The flow through them can be stopped or controlled by placing a short length of plank over the end of the pipe on which the highest water head exists. The most satisfactory drainage arrangement was found to be the installation of a box at each end of these drain lines (Fig. 2). These boxes are usually approximately 2½ feet square by 5 feet deep, and anchored in the side of the levee with posts. The boxes are provided with removable boards on the outside so that the elevation of the liquid in the lagoons can be controlled.

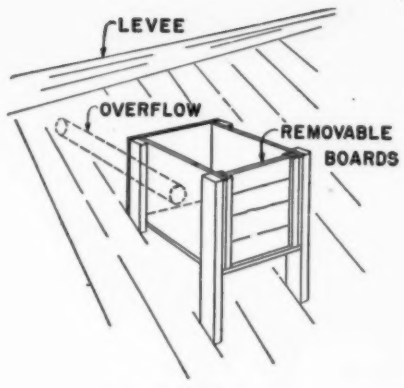


Fig. 2.—Drain Box

From the experience gained over the years, it has been definitely concluded that an underdrain system is not necessary for the satisfactory operation of lagoons.

TABLE II

Digested Sludge Chemical Examination Composite Sample for 1933

Analysis	Per Cent
	Dry Solids Basis
Volatile	48.3
Total organic nitrogen	2.34
Petroleum ether soluble	5.65
Phosphoric acid (P_2O_5)	1.72
	Ash Basis
HCl insoluble	23.12
SiO_2	16.85
Fe_2O_3	4.00
Al_2O_3	9.52
$CaCO_3$	23.97
$MgCO_3$	3.19
SO_4	2.68

Operation and Control

The solids digested in the lagoons were primary, activated, and plain aeration sludges (Table I). No effort was ever made to thoroughly pre-mix the solids of the several sludges as they were pumped into the lagoons. At two periods lasting for several months both ground and unground garbage, amounting to the entire garbage from the city, was satisfactorily digested in the lagoons along with the sewage solids.

No routine laboratory control was established to aid in the operation of the lagoons. In 1933 a composite of sludge being removed from the lagoons was made and the analysis of this composite is given in Table II. This does not mean, however, that a lagoon can just be built and used as a dump for all solids and still maintain satisfactory digestion without the production of objectionable odors. Great care has always been taken in the addition of raw solids so that excessive amounts were never added in short periods of time.

It is desirable to have several lagoons into which sludges can be pumped so that one may be used for several days and then left to stand idle for a few days so that decomposition and separation of solids and liquid can take place. This procedure would not necessarily have to be followed if the lagoon were large enough so that there was a sufficient amount of digested sludge to assimilate and buffer the raw solids being added.

In starting a lagoon it is desirable to fill it with supernatant or digested sludge to a depth of three or four feet before any raw solids are added. The addition of sludge goes on for many months and an effort is made to add solids until it is impossible to add more without the sludge flowing on through to the overflow.

It has been impossible to run solids balances on the lagoons because of the overflowing from one to the other unit, and because of the difficulty in keeping records when changes from one lagoon to another take place during a pumping period. The information on the total pounds of raw solids digested in the lagoons during a sixteen-year period is given in Table III along with the lagoon volume available. It is apparent from these data that solids have been digested at the rate of about six pounds per cubic foot per year.

When a lagoon has been filled completely with sludge it is "laid by" for as long a period as possible before an attempt is made to remove the sludge. It has been found that a sludge lagoon "laid by" for 18 months results in a material with a moisture content as low as 75 per cent. During the 18 months' digesting and dewatering period a portable pump is used to remove free water which will accumulate at the low points in the sludge bed.

When the sludge is ready for removal a motor crane with clamshell bucket and caterpillar treads is brought to the lagoon at the point where the ramp descends from the levee road. The operator then starts loading the sludge onto the trucks of market gardeners who haul it away for fertilizer. The sludge is usually six to eight feet deep when the unloading of the lagoon starts. By the time the shovel has worked its way to the bottom of the ramp the sludge surface has settled with a slope toward the ramp. A hole is then dug in the bottom to serve as a sump for the

TABLE III

Dry Solids Wasted to Lagoons—Pounds per Year

Year	Primary Sludge	Activated Sludge and/or Plain Aeration Sludge	Total	Average Lagoon Volume in Cu. Ft. in Service	Pounds per Cu. Ft. per Year
1926	14,515,000	12,389,000	26,904,000	4,368,000	6.15
1927	14,560,000	10,812,000	25,372,000	4,368,000	5.80
1928	13,836,000	9,942,000	23,778,000	5,562,000	4.26
1929	16,254,000	6,103,000	22,357,000	5,562,000	4.01
1930	17,242,000	10,504,000	27,746,000	5,562,000	4.98
1931	19,024,000	13,418,000	32,442,000	6,398,000	5.07
1932	16,742,000	13,706,000	29,448,000	8,306,000	3.54
1933	13,617,000	17,857,000	31,474,000	9,942,000	3.17
1934	14,983,000	20,236,000	35,219,000	9,942,000	3.54
1935	18,706,000	20,241,000 *1,590,000	40,537,000	9,942,000	4.08
1936	16,998,000	19,045,000	36,043,000	12,238,000	2.95
1937	16,239,000	22,508,000	38,747,000	14,150,000	2.74
1938	15,090,000	30,539,000	45,629,000	14,150,000	3.23
1939	16,519,000	28,585,000	45,104,000	14,150,000	3.19
1940	22,752,000	30,799,000	53,551,000	24,220,000	2.21
1941	24,695,000	30,939,000	55,634,000	24,220,000	2.30
1942	30,907,000	35,006,000	65,913,000	24,220,000	2.72

*Activated sludge.

Location of Lagoons in Relation to Plant in Background

Lagoon Being Filled Supernatant still plentiful.

Overflow Box in Operation Sludge and supernatant liquor at high level.

Winter Scene of Lagoon
Surface partly frozen. Cones caused by gas.

Lagoon Being Dried Out
Sludge approximately 8 ft. deep.

Lagoon Being Dried Out
Growth of weeds on sludge surface.

portable pump, which removes water leaving the sludge and also rain water.

Table IV is a tabulation of the yardage of sludge removed during the past several years and cost of such removal.

The removal and disposal of the sludge from the lagoons in a layout as large as that at Indianapolis is a great problem. It is entirely possible that a portable dryer and incinerator might be built which could be moved into a lagoon for the disposal of all sludge that could not be given away to farmers and market gardeners. If such an arrangement could be made or the sludge could be given away or sold sufficiently fast to completely clean one lagoon per year, it would effectively decrease the volume of lagoon capacity needed to meet the requirements of a city.

General Discussion

Sludge digestion lagoons can be operated without objectionable odors providing sufficient seeding and buffering material is added when a lagoon is being started and the amount of raw solids added each day is not more than can be readily assimilated and decomposed. In the operation of lagoons it is necessary to discontinue the addition of raw solids upon the detection of the slightest objectionable odor. During the cold months great care must be exercised, as it is possible to overload the lagoons during that season without producing bad odors, but when warmer weather comes and fermentation is accelerated, odors will appear because of the overbalance of "green" solids during the period of retarded digestion.

In some instances appreciable depths of scum form on the lagoons and there seems to be no objection to this unless it is because of the weeds that may grow in the scum. It is recommended, however, that the levees be kept free of weeds insofar as possible because it creates a feeling that the lagoons are definitely a part of the sewage disposal plant rather than uncared-for dumps.

During the summer months many rat-tailed maggots grow in the lagoons. If the flies from these maggots should be a problem it is believed that they could be satisfactorily controlled by the use of light oil films or some of the newer materials used for insect control.

Lagoons of more than five feet in depth are, of course, a hazard, and if they are not sufficiently isolated they should be properly fenced.

The cost of operation of the lagoons can be seen from Table IV.

These cost figures do not include interest or depreciation and they are based upon the sewage flow that was given primary treatment. Not all of the sewage was given complete treatment during these years.

Conclusions

1. A mixture of primary sludge, activated sludge, plain aeration sludge, and garbage can be satisfactorily digested without odors in open lagoons.
2. If the lagoons are used for digestion only, at least six pounds of solids can be digested per year per cubic foot of lagoon capacity. This is equivalent to 0.17 cu. ft. of lagoon capacity per pound of solids.
3. If the lagoons are used for digestion and also as dewatering beds, a capacity of 0.37 to 0.40 cubic feet per pound of raw solids per year is sufficient, providing the air-dried sludge can be removed as rapidly as it is ready for hauling.
4. Using the above capacities, it is possible to discharge a supernatant of good quality to the receiving stream.

Reference

[1]*Engr. News Record*, Feb. 9, 1928.

TABLE IV

Digested Sludge Removed and Cost of Operation of Lagoons

Year	Cubic Yards	Cost per Mil. Gal. of Sewage Given Primary Treatment*
1926	.....	$0.96
1927	5,000	1.68
1928	10,000	0.68
1929	16,128	0.61
1930	14,336	0.58
1931	23,616	0.51
1932	12,438	0.26
1933	5,224	0.30
1934	20,208	0.23
1935	13,129	0.23
1936	25,819	1.09
1937	9,343	0.39
1938	12,198	0.20
1939	35,050	0.31
1940	25,128	0.48
1941	17,077	0.57
1942	14,878	0.42
Average		$0.56

*No capital charge, interest, or depreciation included.

HOW TO USE DDT FOR INSECT CONTROL

Including a Recommendation Covering Its Application for Filter Fly Control

By

L. F. WARRICK and **G. F. BERNAUER**

Chief State Sanitary Engr. *Senior Asst. State Sanitary Engr.*

Wisconsin State Board of Health
Madison, Wis.

OUT of World War II came DDT, which proved to be the best allaround insecticide ever developed to control insects which bring discomfort, disease and death to men at war. Now that the time has come to put it to work on the home front there is danger that the average person may expect too much of this so-called "miracle insecticide."

Our knowledge of the practical use of DDT in home and garden is still far from complete. Use of the material in this country is as recent as November, 1942, and although large amounts have been used here and overseas, it was restricted and used only for specific purposes by trained personnel under careful supervision. Results of this use indicated that for certain purposes and under certain conditions, DDT can be safely and effectively used by the average person.

One word of warning is necessary, however. DDT is not a cureall. It is not effective against all insects and is slower in action against certain insects than some of the more common insecticides already in use. It has little effect on chiggers and chicken mites and its value against certain other insects is not fully confirmed.

What Is DDT?

The technical grade chemical is a harmless-appearing, white, practically odorless powder resembling flour with lumps, since the DDT has a tendency to stick. It gets the name DDT from the first letter of each part of its chemical name, which is dichloro-diphenyl-trichloroethane. DDT does not dissolve in water and therefore cannot be mixed in pure form with water for use as a spray. It is soluble in oils such as kerosene and in certain commercial solvents, xylene being the most common.

How DDT Kills

DDT differs from previous insecticides both in its manner of killing and its lasting or residual effect. When properly applied to the ceilings, walls and screens of homes, it has been known to kill flies and mosquitoes for as long as seven months. It can be relied on to remain entirely effective for at least three months. Apparently DDT is absorbed through the insects' feet as they walk over a spray deposit or DDT residue. After a short period of exposure the affected insects become restless, drag their legs, and their movements become jerky and spasmodic. They may turn on their backs and be unable to right themselves. Finally they may develop tremors (the so-called "DDT's") and die. However, death may not take place until hours later. Mosquitoes and flies often move toward the light when first affected and may escape from the room to die elsewhere. So don't be disappointed if you fail to find numerous dead insects after you've applied DDT. The best test of DDT's effectiveness is the *absence of live* insects, not the presence of dead ones.

Remember, DDT is not a substitute for screens and other santitary measures! Even though you kill the insects already present, new ones may enter if sanitary precautions are neglected.

Read the Label Before You Buy

Several products containing DDT have appeared on the market and others are on the way. The important thing in purchasing DDT is to make sure you get the proper strength solution or dry mixture for the application intended. Following are the more common prepared products now available:

1. **Dusts.** A number of dry mixtures of DDT are becoming available for dusting. They contain from 5 to 10 per cent DDT diluted with some powder (carrier) such as talc or pyrophyllite. The label will tell you how much DDT is contained. For most uses a dust containing not less than 10 per cent DDT (one part of DDT in nine parts of carrier) is recommended.

2. **Oil Solution.** For use as a residual spray, solutions of DDT in highly refined, deodorized, white kerosene or in other commercial solvents are available. Most of these sprays will probably contain 5 per cent or less DDT. *For use as a residual spray they should contain at least 5 per cent DDT.*

3. **Emulsions.** Although DDT is not soluble in water, it readily dissolves in some organic solvents and concentrations of 25 to 40 per cent can be obtained. These solutions can then be diluted with water to the concentrate desired. Xylene is the solvent commonly used with DDT to create an emulsion. When purchasing DDT in emulsion, read the label to find out how much DDT it contains. Follow the directions on the label to dilute it to a 5 per cent or more concentrated spray.

Those individuals who intend to use larger quantities of DDT regularly in the treatment of apartment houses, restaurants, dairy barns, and the like may wish to prepare their own emulsion concentrate. But in general, the average user will prefer to buy a ready-made product requiring only simple dilution with water.

If desired, such an emulsion concentrate (35 per cent DDT) can be prepared by dissolving 3 pounds of technical grade DDT powder in 3 quarts of xylene and then adding 6 fluid ounces of an emulsifying agent. This will make about a gallon of concentrate which can be diluted with water (1 part concentrate to 6 parts water) to make about seven gallons of 5 per cent spray. Strain the concentrate carefully before diluting with clean water to avoid clogging the sprayer.

At the time this is written the approximate cost of such an emulsion concentrate is about $2.50 per gallon. The net cost of the finished 5 per cent DDT emulsion spray will thus be approximately 35c per gallon. One gallon of this spray will apply an effective DDT residue to about 950 square feet of surface.

4. **Suspensions.** A wettable DDT powder is also available, containing an additional chemical which permits the powder to mix readily with water, distributing small particles of DDT throughout the spray. A 5 per cent spray can be prepared from such a wettable powder by diluting with the proper amount of water. The amount of water necessary depends on the concentration of DDT in the product, which is shown on the label. This DDT suspension can be applied to surfaces through a spray. It has no odor, presents no fire hazard and is harmless when applied to the skin of man or the coats of animals. When the water evaporates, small flecks of DDT and carrier will remain on the sprayed surface. Therefore this application is not recommended for furniture, dark colored paints, varnished floors and window glass, but it can be effectively and easily applied where such spotting is unimportant.

5. **DDT Fly-Sprays.** Many manufacturers of well-known fly sprays are adding small amounts of DDT (one-half to 2½ per cent) to their commercial sprays. However, the addition of DDT to such "quick-killing" compounds tends to confuse the purchaser in method of application. The quick killing sprays are intended to affect the respiratory system of the insect and require diffusion in the air for effectiveness, with frequent applications. DDT, however, is primarily a central nervous system poison and, when properly applied to the surface as a *residual* spray, retains its potent killing effect for months.

6. **Paints.** Whitewash paints and oil base paints containing DDT are being produced but since little is known about them, the manufacturer's directions should be followed. No recommendations as to their effectiveness can be made at this time.

7. **Straight DDT.*** A home-made oil spray can be prepared by dissolving DDT in a highly refined, deodorized, white kerosene. One cup of straight DDT powder (*not* a commercially prepared dust) thoroughly dissolved in one gallon of kerosene will make about a 5 per cent DDT oil spray. Strain the solution before using to remove particles that might clog the nozzle. Do not use ordinary kerosene—use only white kerosene. The mist from this spray is highly combustible.

8. **Aerosols.** Aerosol "bombs" were used by the armed forces for spraying insecticide under pressure by use of a propellant. They contain 3 per cent DDT, 2 per cent pyrethrum, cyclohexanone as a solvent for the DDT, an activator for the pyrethrum and Freon-12, a liquid gas under pressure which provides the force for the spray. Such a bomb is a space sprayer which kills insects present at the time but affords only a brief residual effect. Aerosols are useful for freeing a small outdoor area of insects for periods of one or two hours, or possibly longer.

Flies. The use of DDT as a residual spray is the most effective way of controlling house flies. Apply a coating of 5

*Formerly termed "Technical Grade," but now known as 89°C. setting point D.D.T.

per cent DDT solution or emulsion to the surface and repeat in three months. Use a small hand sprayer, an air pressure garden sprayer, a wide paint brush or a roller applicator to treat walls and ceilings. Be sure to apply the spray to the fly's favorite resting places—on the ceiling, around cracks and crevices, along edges of ceiling strips and doorways, and all other edges in the room. Electric cords or switch cords should be sprayed with DDT solution since flies cling to these and will receive a toxic dose. Soaking strips of bandage gauze, heavy string or cord, in DDT solution and hanging them up may serve the same purpose. In some places fly control can be accomplished merely by spraying these special places and not treating the whole room. In treating screen doors and windows, apply the 5 per cent DDT solution on the wire screen with a wide brush. A felt roller can also be used.

Mosquitoes. Residual spraying for the control of anopheline mosquitoes has now become a routine procedure in the fight against malaria both in this country and in military operations overseas during the war. In houses sprayed with 5 per cent DDT solution, mosquitoes infected with malaria parasites will have ample opportunity to rest on a treated surface and be killed before they can spread the disease to others. Other types of mosquitos which are simply annoying can also be controlled by residual spraying. Use the same methods of application as described for flies.

Cockroaches. A 10 per cent DDT powder is effective against cockroaches and is less poisonous to pets and human beings than the sodium fluoride now used in most roach powders. Use a small hand dust gun to force the dust into cracks and crevices, along shelving, behind sinks, around pipes and in any other possible hiding places. Wipe away excess dust with a cloth. Allow time for the dust to take effect—one week may elapse before you notice any marked reduction in the roach population when dust is used.

For quicker results use a 5 per cent DDT spray (either oil solution, suspension or emulsion). Force the spray into the hiding places described above, and any other places where roaches have been seen. Roaches actually hit with the spray generally die quickly.

A combination of spraying for immediate control plus residual dusting in places not reached by the spray is the most effective cockroach control.

Bedbugs. DDT has proved superior even to pyrethrum sprays formerly used to control these pests. A single treatment of 5 per cent DDT spray properly applied to mattresses and bedsteads will "bugproof" them for as long as 6 months. Use a small hand sprayer to force DDT solution into each crack and joint of the bed, also the springs. Spray all surfaces—top, bottom and sides—until they have a misty-wet appearance. Be sure to force the spray into seams and folds where bedbugs hide. Don't expect a complete kill until 48 hours after exposure of the bugs to the deposited DDT.

Fleas. Dust the infested rooms and basement thoroughly with 10 per cent DDT powder, giving special attention to sleeping places or places where animals generally lie down. If left in place the treatment may control fleas as long as 80 days after dusting. *Never use DDT oil solutions on animals.* A 5 per cent DDT spray (either in oil solution or in an emulsion) may be applied to the floors, rugs, furniture and sleeping places of the pets. Most dogs of average size may be safely dusted with about a tablespoon of 10 per cent DDT powder. Cats, however, should not be treated with DDT dusts because they lick themselves and may swallow enough DDT to cause illness.

Warning—DDT dissolved in oil may be absorbed directly through the skin of animals with fatal results. Kerosene and other oils in themselves are poisonous to the skin. Several instances are already on record where valuable animals have been killed by spraying or dipping in DDT oil solutions.

Lice. Body lice are usually found in clothing and not on the body proper. Sift the 10 per cent DDT powder over the entire inner surface of the underwear, taking special care to rub it into seams. The inside of the shirt, trousers, hat and other clothing should also be treated. One ounce (2 heaping tablespoons) of 10 per cent DDT powder per treatment will remain effective for three weeks or longer if the clothing is not washed, although clothing treated in this way will still kill lice after one washing in warm soapy water.

Head lice. A teaspoon of 10 per cent powder should be thoroughly rubbed into the hair. Since DDT does not kill eggs or nits, repeat the treatment in 8 to 10 days.

Crab lice. Lightly dust the affected parts with a 10 per cent DDT powder. Repeat application in 8 or 10 days to kill any young lice hatched in the interval.

Brown Dog Tick. Use a 10 per cent DDT powder, distributing the dust evenly over the dog's entire body. A coarse salt shaker can be used. One heaping tablespoon should be applied to the average sized animal. Rub the powder into the fur with an ordinary cloth glove or brush. Infestations in the home can be treated by applying 10 per cent DDT powder or 5 per cent DDT spray to cracks and crevices about baseboards, to floors, under sides of rugs and other floor coverings, window casing and other hiding places of the ticks. The dust kills ticks slowly. Leave it on fabrics, floors and other places for about two weeks, then wipe up powder or use vacuum cleaner. A second treatment may be necessary.

Ants. First try to find the points of entrance into the house. Treat these areas with a heavy spray deposit of DDT. Paint or spray 5 per cent solution over the door sills, door frame, back steps, cupboard, shelves, drawers and other places where ants are seen. Dust ant hills or nests with 10 per cent DDT powder and it will be carried down into the nest and gradually kill the whole colony. Don't spray them with oil solutions or emulsions.

Sand Flies. Paint screens with heavy application of 5 per cent DDT solution and spray, or paint the walls and ceilings near lights. Treatment should be effective for several weeks.

Silverfish. The treatment recommended for cockroaches will be equally effective against silverfish.

Clothes Moths. Clothing can be protected from moth damage by spraying all surfaces with DDT in oil solution or emulsion before storing. A hand sprayer or vacuum cleaner sprayer can be used to apply a fine mist over the surface of the fabrics. The inside of closets, trunks and other storage places may also be treated.

Carpet Beetles. Spray rugs, carpets, clothing and upholstered furniture with DDT solution. Especially treat the angles of upholstered furniture, cracks about baseboard and other places where dust and lint collect.

Precautions in Using DDT

Although DDT is deadly to many insects, it is not harmful to man if properly handled. As with any insecticide, however, certain precautions are necessary in order to avoid any possible harmful effects.

1. Cover food, dishes and cooking utensils or remove them from room when spraying or dusting with DDT.
2. If DDT is swallowed accidentally, drink some mustard water immediately. This is made by adding one tablespoon of mustard to a glass of warm water. The mustard water will cause vomiting. Call or see a physician immediately.
3. DDT in oil solution is readily absorbed through the intestines and also directly through the skin. Never let DDT oil solutions remain on the skin or saturate clothing. Wash hands and exposed skin with warm, soapy water. If oil solutions or concentrates are spilled on clothes, change them promptly.
4. DDT in dust form may be absorbed through the skin if greases, oils or greasy skin lotions are already present on the skin.
5. Avoid inhaling the mist when spraying DDT. Ventilate the room while spraying.
6. Where extensive spraying is done, wear gloves, goggles and a respirator.
7. Do not apply DDT oil solution to the skin or fur of animals.
8. Do not substitute DDT for good sanitation and cleanliness.

Experiences in Fly Filter Control with DDT

The effective use of DDT in elimination of insect pests has given rise to considerable speculation regarding its suitability for control of the psychoda fly in the vicinity of trickling filters at sewage treatment plants. Experiments in this direction have been divided into two types: First, those which attempt destruction of the adult flies by means of DDT application to the filter surroundings, and second, those which have applied the chemical directly to the filter medium in an effort to kill fly larvae.

Wisconsin experiments during the summers of 1944 and 1945 were limited to spraying DDT on areas near sewage filters either in emulsion form or dissolved in kerosene. At one plant a 3 per cent emulsion was sprayed on the outside and top of the filter walls, the upper portion of the inside walls and the outer six inches of filter medium, at a density of approximately 5 ounces of DDT per 1,000 square feet of area. In one case the fly nuisance near the filters and at the control building was reduced considerably and the treatment remained effective until heavy rains removed the DDT from the surfaces. In similar experiments at another plant the treatment was not nearly as effective.

At West Bend spraying of surroundings was almost entirely ineffective due to winds carrying the flies across sprayed areas to

nearby residences. Construction of a temporary barrier in the form of two thicknesses of cheesecloth attached to 8 ft. high supports arranged around half the filter circumference was next undertaken. This barrier was sprayed with DDT solution in kerosene with the intent of killing the flies when they alighted on the cloth. While there was no wind the treatment appeared to be effective; however, moderately strong winds carried the flies over and around the barrier to the extent that they again appeared in considerable quantities at the residences.

In the past, application of DDT directly to the filter medium has been discouraged in Wisconsin because of the danger of toxic effect on fish in streams receiving plant effluent. As little as 0.07 ppm. of DDT will kill certain species. During the current summer, DDT has been applied to the filter influent at the Beaver Dam, Wisc., plant where a controlled stream flow permitted sufficient dilution for the period of DDT addition. A dose of 1.0 ppm. was applied continuously to the filter influent for two hours. No immediate benefits were noted but after three days the number of flies emerging from the filter had decreased to practically zero, and few larvae could be detected on the filter stone. Apparently DDT applied in this manner kills the larvae but has little or no effect on the adult flies. Ten days after treatment a severe fly nuisance again occurred. This experience indicates that DDT should be applied about every seven days in order to control the adult fly population satisfactorily. Tests of 5 day B.O.D. in the plant effluent before and after treatment indicated no impairment of plant efficiency by the DDT application.

Attempts have also been made to control flies by spraying the surface of the filter medium with a 10 per cent solution of DDT in xylol at a density of 2 ounces of DDT per thousand square feet of area but the results have been unsatisfactory.

These experiments in Wisconsin seem to indicate that the most satisfactory method for use of DDT in control of filter flies lies in application of an emulsion to the filter influent in order to effectively reach the fly larvae. It must be certain, however, that the dilution afforded in the receiving stream is sufficient to prevent hazards to aquatic life. If it is not possible to secure such dilution, limited benefits may be obtained by application of areas near the filter as well as to other points in the plant grounds where nuisances occur.

THE SURFACE AREA OF CYLINDRICAL OBJECTS

A Chart Applicable to Tanks, Pipe and Pipe Lines, Drums, Conduits, Poles, Stacks, Standpipes, etc., etc.

By W. F. SCHAPHORST, M.E.
Newark, N. J.

THE dotted line drawn across the chart shows that if the diameter of a cylinder, pipe, tube, tank, or what not, is 20 inches (column A) and the length is 191 feet, (column C), the total area is 1000 square feet, as revealed where the line crosses column B.

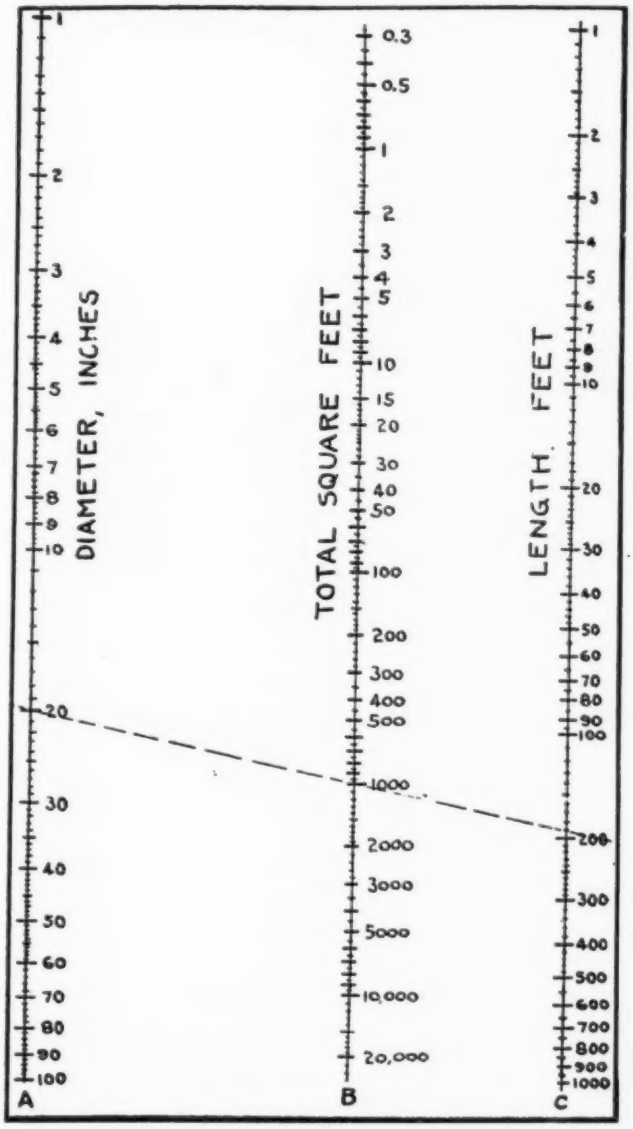
The chart covers a wide range—from 1 to 100 inches in diameter and from 1 to 1000 ft. length. But it can be applied to any diameter or length, as follows: Let us suppose that you want to build a vertical tank of any material, 200 inches in diameter and 191 ft. high. What will be the area? Those figures have been chosen purposely to show that the same dotted line already drawn across this chart can be used to solve the problem. The answer will be 10,000 sq. ft. instead of 1000 sq. ft. for reasons that are obvious.

In other words, if you add a cipher to the figures in column A you must also add a cipher to the answer in column B. If you add 2 ciphers in column A you also add 2 ciphers in B. And so on. The same is true of column C. To make sure that everything is understood let us add 2 ciphers to the 20 in column A, making the diameter 2,000 inches. And let us add 2 ciphers to the 191 in C making the height 19,100 feet. The number of square feet will then be 10,000,000 because we must add a total of 4 ciphers to the figure in column B.

Of course the last example was just to illustrate the wide range of such a small chart if one considers the multiples of 10 or 100 involved and multiplies the figure in Coumn B accordingly. In this case we had 100 × 20 inches and 100 × 191 feet, so we simply multiplied the 1000 sq. ft. figure by 100 to take care of the 100 diameters and the resulting figure is then multiplied by 100 to take care of the 100 heights or lengths; i.e.—1000 × 100 = 100,000 and the 100,000 × 100 = 10,000,000.

Now if the diameter is 200 inches and the height is only 19.1 feet the line crosses Col. B at 100 sq. ft., so multiply only by 10 diameters (10 × 20) and the surface area of this tank or standpipe is found to be the same 1000 sq. ft. as that of the 20 inch cylinder 191 ft. high or long.

The chart may be also used to determine the most economical ratio of diameter to height for tanks of required volume—i.e., the diameter and height combination which gives the least number of square feet of surface area is the most economical in materials of construction. In short, the chart may be used "backwards" as well as "forward" and for several purposes.



Cylindrical Surface Area Chart

INNIS, SPEIDEN & CO.

117 LIBERTY ST., NEW YORK 6, N. Y.

BOSTON • CHICAGO • CINCINNATI • CLEVELAND • GLOVERSVILLE • PHILADELPHIA

Ferri-Cl$_3$or
Ferric Chloride
The FAST Coagulant!

AS A COAGULANT FOR SEWAGE AND INDUSTRIAL WASTES

The chemical treatment of sewage and industrial wastes is an effective and economical method of increasing the efficiency of the ordinary sedimentation plant. Such treatment requires but little plant construction or capital investment. It provides a high overload capacity and flexibility in proportioning to produce the degree of purification required. Seasonal loads are readily handled with the Ferri-Cl$_3$or treatment.

Ferri-Cl$_3$or coagulates sewage and industrial wastes, thus causing more rapid precipitation in sedimentation plants and faster filtering through vacuum filtration systems. It is most effective in the pretreatment of industrial wastes which offer change in characteristics almost hourly.

Experience has shown that Ferri-Cl$_3$or is also an *economical* coagulant for sewage and a wide range of industrial wastes.

FOR COAGULATING SEWAGE

Ferri-Cl$_3$or provides an inexpensive and efficient method of dealing with plant overloads, and reduces original plant investment by increasing the capacity of the sedimentation plant.

AMOUNT of Ferri-Cl$_3$or to be Used

The accepted procedure in determining the dose of Ferri-Cl$_3$or required to coagulate a given sewage is to set up "jar tests" with sewage to be tested. 2 qt. Mason Jars and stock solutions of Ferri-Cl$_3$or and lime, consisting of 10 grams per liter of distilled water, are used. Place one liter of sewage to be tested in each of several Mason Jars. Add to the sewage in each jar, successively larger doses of Ferri-Cl$_3$or stock solution. Stir all samples thoroughly for several minutes and let stand for 1 hour. Observation of the several samples will determine the best dosage. If lime is required to provide sufficient alkalinity for satisfactory coagulation, follow the same procedure outlined for Ferri-Cl$_3$or. The amount in lbs. of Ferri-Cl$_3$or or lime required equals the number of c.c. used in the selected test x 10 x total sewage flow (m.g.d.) x 8.33.

ISCO FERRIC CHLORIDE

FOR SLUDGE CONDITIONING

For efficiency and economy—ISCO Ferri-Cl$_3$or produces the best sludge floc for filtration, compared weight for weight with other commercial coagulants. Because of this fact, ISCO Ferri-Cl$_3$or is accepted as the lowest-cost powerful sludge coagulant on the market.

AMOUNT of Ferri-Cl$_3$or to be Used

Using the Buchner Funnel Test, the time periods required for the vacuum to break with varying quantities of coagulant are recorded. 2 to 3 minutes is satisfactory and 1 to 1½ minutes is very good and should be used for plants where the sludge is held, as in batch-mixing.

Various combinations of Ferri-Cl$_3$or and lime should be tested until the relative quantities for optimum operation are determined. The approximate quantities of chemical to be used in the plant can be determined from the laboratory test, provided, of course, that the same strength chemicals are used in the plant. The quantity of Ferri-Cl$_3$or solution in gallons per 1,000 gallons of sludge will be 5 times the c.c. used per 200 c.c. of sludge in the test. Likewise, the quantity of lime in pounds per 1,000 gallons of sludge will be 42 times the grams used per 200 c.c. of sludge.

PREPARATION of Ferri-Cl$_3$or Solution

Saturated solutions of Ferri-Cl$_3$or are heavier than water, i.e.: you may have clear water above and undissolved crystals at the bottom of your mixing tank. Therefore, we recommend dissolving by one of the following effective and efficient methods:

1. Automatic gravity circulation by placing the salt on a wooden grid elevated or suspended one-half way in the tank.

2. Mechanical mixing by (a) stirring, (b) air agitation, and (c) liquid recirculation.

3. Melting: Ferri-Cl$_3$or melts at 98.6 to 102.2°F. and so can readily be liquefied by relatively small amounts of heat from exhaust or live steam, flue gases, oil, gas or electricity. The dissolved salts can be poured into the water.

Ferri-Cl$_3$or
Ferric Chloride
The FAST Coagulant!
Ferric Chloride 60% ($FeCl_3$)

is ISCO's registered name for Ferric Chloride developed and manufactured especially for Sewage and Water Treatment.

NOMOGRAPH FOR DETERMINATION OF SLUDGE FILTRATION DATA

By CHARLES M. GARD
Sanitary Engr., Hdqtrs. 2nd Service Command, New York, N. Y.

THE plant for which this nomograph was originally prepared is a small plant having an average daily flow of about 0.3 mgd. It provides complete treatment with standard trickling filters and separate heated sludge digesters. At this plant a 6 ft. x 3 ft. dia. vacuum filter was provided. Auxiliary facilities for sludge conditioning prior to filtration provided means for the addition of lime and a ferric iron salt. A 40° Bé. liquid ferric chloride was used which was procured in 12 gal. glass carboys. This stock was usually diluted 1 : 1 with water and fed with a Proportioneers' chemical feeder from a rubber-lined steel tank of approximately 30 gal. capacity. The lime was fed with a Syntron feeder, dry feed type.

Information Desired

Part of the usual information desired in the filtration of sewage sludge is:

(1) Quantity of anhydrous chemicals used in lb., and in lb. per 100 lb. of dry sludge solids; and

(2) Dry solids of filtered sludge in lb. (total), and in lb. per unit of filter area per hr.

Obtaining these four values would appear to be relatively easy. However, the procedure required is actually more involved than one might think.

With the facilities and equipment available at this particular plant the procedure that had to be followed was to determine the dry lime feed in grams per min. and the ferric chloride in ml. per min. of whatever dilution of the 40° Bé. stock solution that was being used. These values were obtained by making determinations at several times during the filter run and averaging the results.

To illustrate the amount of calculation involved without the use of the nomograph, the following example is given:

Assume that

(1) Dry lime feed is 200 grams/min.

(2) $FeCl_3$ feed is 250 ml./min. of a solution of 42° Bé. stock diluted in 1 : 1 with water.

(3) Time of filter run is 6 hrs.

(4) 3000 gals. of 5 per cent solids sludge are filtered.

(5) Filter area is 55 sq. ft.

Lb. of dry solids filtered =

$$(3000)\ (8.33)\ (.05) = \underline{1250}$$

Lb. dry solids per 100 sq. ft. per hr. =

$$\left(\frac{1250}{55x6}\right)\ (100) = \underline{378}$$

Lb. of lime fed =

$$\left(\frac{200}{453.4}\right)\ (6)\ (60) = \underline{159}$$

Lb. lime per 100 lb. dry solids =

$$\left(\frac{159}{1250}\right)\ (100) = \underline{12.8}$$

Lb. dry $FeCl_3$ =

$$\left(\frac{250}{1000x3.78}\right)\ (2.31^*)\ (6)\ (60) = \underline{55}$$

Lb. of dry $FeCl_3$ per 100 lb. dry solids =

$$\left(\frac{55}{1250}\right)\ (100) = \underline{4.4}$$

(*Note—1 gal. of diluted stock as used contains 2.31 lbs. dry $FeCl_3$).

It is realized that the determinations of the quantity of chemicals used during the filter run can be simplified somewhat by different means of measurement. However, the mathematical steps involved in obtaining the final results will remain substantially the same regardless of variations in the measuring technique.

Use of the Nomograph

The same basic data in the example given above will be used to illustrate the use of the nomograph. The same example is indicated on the nomograph also. Using a straightedge, the following sequence of steps are performed:

1. Connect 200 (lime) on scale "l" with 6 on scale "t" and read 159 lb. of dry lime on scale "C."

2. Connect 250 ($FeCl_3$) on scale "f" with 1 : 1 dilution ratio on scale "B" and locate point of intersection on pivot line.

3. Connect pivot line point located in step 2 with 6 on scale "t" and read 55 lb. dry $FeCl_3$ on scale "C."

4. Connect 5 (of solids) on scale "p" with 3000 on scale "S" and read 1250 lb. dry solids filtered on scale "D."

5. Connect point on scale "D" located in step 4 with point located on scale "C" in step 1 and read 12.8 lb. dry lime per 100 lb. dry solids on scale "P."

6. Connect point located on scale "D" in step 4 with point located on scale "C" in step 3 and read 4.4 lb. dry $FeCl_3$ per 100 lb. of dry solids on scale "P."

Then by simple calculation

$$\left(\frac{1250}{55x6}\right)\ (100) = 378 \text{ lb. dry}$$

solids filtered per 100 sq. ft. per hr.

Limitations

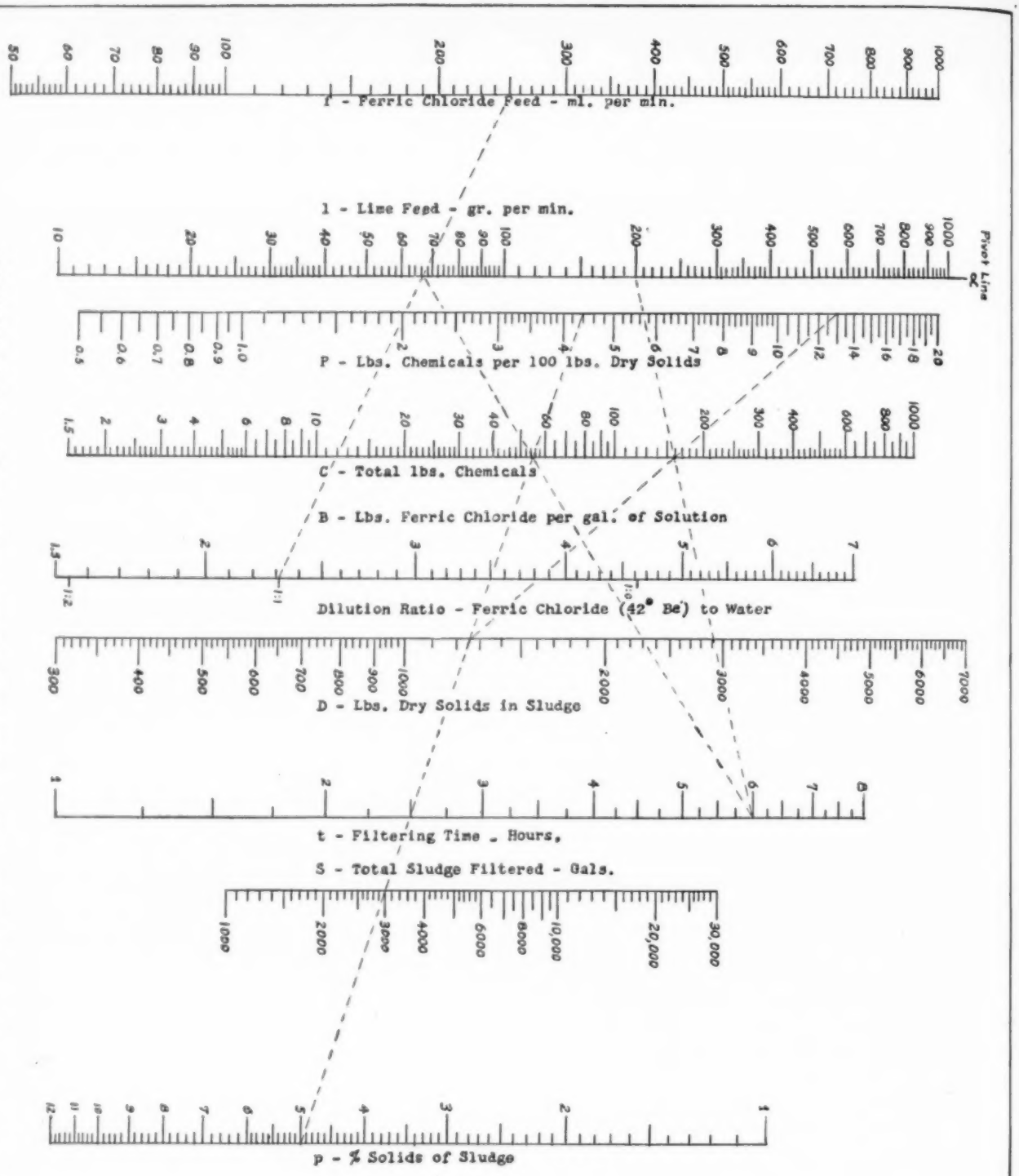
The nomograph has certain limitations. Since it was prepared primarily for use at a small plant, the range of the scale values may be exceeded at larger plants where larger quantities of sludge are handled. This can be overcome by using fractional parts of the actual total values for scales "f," "l," "t," and/or "S," and making appropriate correction in the final answers obtained from the nomograph. For example, by using fractional values of ¼, ⅓ or ½ would give correction factors of 4, 3, and 2, respectively.

The scale for the dilution factor of the ferric chloride is designed for 42° Bé. stock. However, if other concentrations of ferric chloride stock are used, the lb. of dry $FeCl_3$ per gal. of solution for any dilution used can be predetermined and this value used on the "B" scale, disregarding the recorded dilution ratios on the nomograph.

Summary

Where vacuum sludge filtration is used, this nomograph should facilitate computation of certain desired data as described herein. The author's experience has been that the steps involved in using the nomograph are readily learned by a plant operator and can with a little practice be used by him with assurance of accuracy. The same operator might, however, experience some difficulty in following through the regular mathematical computations involved, and at least would spend more time doing them. The use of the nomograph is particularly time-saving where several calculations have to be made.

NOMOGRAPH FOR THE DETERMINATION OF SEWAGE SLUDGE FILTRATION DATA


f - Ferric Chloride Feed - ml. per min.
l - Lime Feed - gr. per min.
Pivot Line
P - Lbs. Chemicals per 100 lbs. Dry Solids
C - Total lbs. Chemicals
B - Lbs. Ferric Chloride per gal. of Solution
Dilution Ratio - Ferric Chloride (42° Be) to Water
D - Lbs. Dry Solids in Sludge
t - Filtering Time - Hours.
S - Total Sludge Filtered - Gals.
p - % Solids of Sludge

KEY -

1 - t
f - B
x - t
p - S
D - C

EXAMPLE -

Assume
l = 200 gr. per min.
t = 6 hrs.
f = 250 ml. per min.
B = 2.31 lbs. per gal. (42° Be. Ferric Chloride diluted 1:1 with water)
p = 5% sludge solids
S = 3000 gals. sludge filtered.

Find
C = 159 lbs. of lime
C = 55 lbs. of ferric chloride
D = 1250 lbs. of dry sludge solids
P = 12.8 lbs. lime per 100 lbs. dry solid
P = 4.4 lbs. ferric chloride per 100 lbs. dry solids

Prepared by C.M.Gard
Feb.12,1945

% PROPORTIONEERS, INC. %

91 Codding St., Providence 1, R. I.

Atlanta, Ga.
Beloit, Wis.
Birmingham, Ala.
Charlotte, N. C.
Chicago, Ill.
Cleveland, Ohio
Dayton, Ohio
Denver, Colo.
Des Moines, Iowa
Detroit, Mich.
Elyria, Ohio
Fargo, N. D.
Huntington, West Va.
Jackson, Miss.
Kansas City, Mo.
Los Angeles, Cal.
Louisville, Ky.
Medford, Mass.
Miami, Fla.
Nashvile, Tenn.
New Orleans, La.
New York, N. Y.
Niagara Falls, N. Y.
Oak Harbor, Ohio
Omaha, Neb.
Philadelphia, Pa.
Pittsburgh, Pa.
Richmond, Va.
St. Louis, Mo.
St. Paul, Minn.
Salt Lake City, Utah
San Antonio, Texas
San Francisco, Cal.
Seattle, Wash.
Syracuse, N. Y.
Tampa, Fla.
Troy, N. Y.
Tulsa, Okla.
Washington, D. C.

CHEMICAL FEEDERS FOR WATER AND SEWAGE TREATMENT

DIAPHRAGM AND PLUNGER TYPE LIQUID PROPORTIONING PUMPS.

MOTOR DRIVEN AND HYDRAULICALLY OPERATED MODELS.

MANUALLY ADJUSTABLE AND AUTOMATIC PROPORTIONAL UNITS.

DESIGNS FOR HIGH OR LOW PRESSURE.

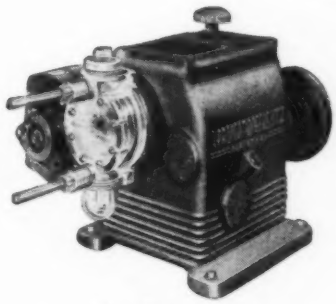


Fig. 1
Heavy Duty Chem-O-Feeder
0-8 gal./hr.
0-100 lbs./sq. in.

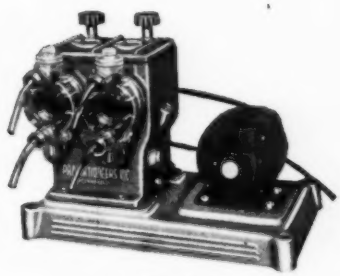


Fig. 2
Duplex Chem-O-Feeder
0-16 gal./hr.
0-100 lbs./sq. in.

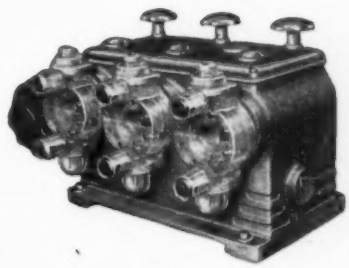


Fig. 3
Triplex Chem-O-Feeder
0-24 gal./hr.
0-100 lbs./sq. in.

Fig. 4
High Pressure Midget
Chlor-O-Feeder
0-6 gal./hr.
30-200 lbs./sq. in.

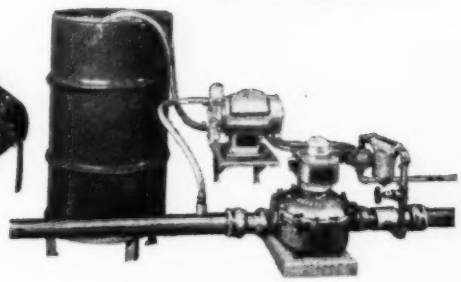


Fig. 5
Low Pressure Automatic and
Proportional Chem-O-Feeder
0-5 gal./hr.
4-100 lbs./sq. in.

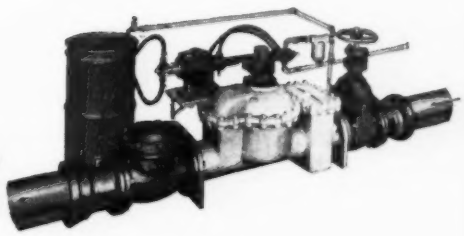
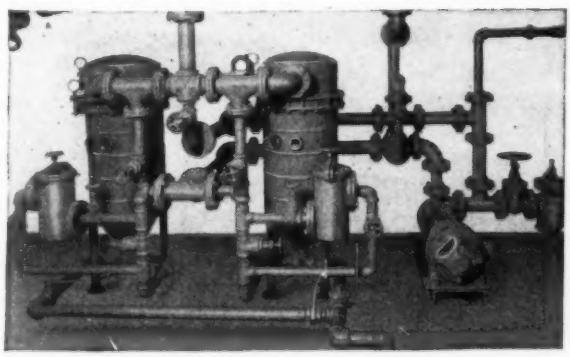


Fig. 6
High Pressure Automatic and
Proportional Chem-O-Feeder
0-5 gal./hr.
30-200 lbs./sq. in.



PUR-O-CEL DIATOMACEOUS EARTH FILTER

%Proportioneers% new Pur-O-Cel Diatomaceous Earth Filter has outstanding advantages: It utilizes thin mats of interlaced particles of diatomaceous earth instead of the conventional sand filter bed and produces unusually clean, brilliant water even at rapid flow rates. Filtering efficiency is so high that amoebic dysentery cysts and many bacteria are removed. The filter is exceptionally compact and easy to operate. With Pur-O-Cel, filtering becomes a simple, mechanical operation. Write for Buletin 1550.

Bring us your water treating and proportioning problems.

%PROPORTIONEERS, INC.%, 91 Codding St., Providence 1, R. I.

"CHEMICAL FEEDER HEADQUARTERS"

Get the Facts on Hooker Chemicals from our New General Products List

We've increased the size of our General Products List from 4 to 20 pages. Several new products have been added and you will want to be brought up to date on our chemicals. The increase in pages comes from an endeavor to make it easier for you to get the information you want about Hooker Chemicals.

Larger type, graphic formulas, and a new format facilitate your finding the chemicals in which you are interested. Included are description, principal physical and chemical properties, uses, and shipping containers. This new products list also describes briefly the various chemical processes and facilities which Hooker has available for industry.

You who are not yet acquainted with Hooker Chemicals will find this new Products List an excellent introduction to a source for industrial chemicals of high purity; it will also pay you to refer to this Bulletin whenever you need chemicals. Feel free, too, to call on Hooker's Technical Staff for advice and help on the application of Hooker Chemicals to your problems.

The words "Bulletin 100" on your business letterhead will bring you a copy of the Hooker General Products List.

HOOKER
ELECTROCHEMICAL
COMPANY
Buffalo Ave. & Ward St., Niagara Falls, N. Y.
New York, N. Y. Wilmington, Calif.
Tacoma, Wash.

HOOKER CHEMICALS

From the salt of the earth

Caustic Soda
Paradichlorbenzene
Muriatic Acid
Chlorine
Sodium Sulfide
Sodium Sulfhydrate

DOSAGE CONTROL IN SEWAGE CHLORINATION

By GEORGE E. SYMONS
Assoc. Editor, Water Works and Sewerage

IN SEWAGE treatment works employing disinfection by chlorination, some control of chlorine dosage is necessary to meet the varying needs. The larger the plant the more important is such control, both from the standpoint of economy and bactericidal efficiencies. Efficient and non-wasteful usage is important and there is particular merit in efficient application control in the sanitary field.

Quite obviously, any system of continuous chlorine dosage control to meet variable conditions will produce the most efficient results[1]. Lacking continuous control, some "programmed step by step method of chlorination"[1] offers the best substitute. The time interval of the steps may be dictated by the size of the treatment works, the variables of chlorine demand and flow, the plant personnel and operation routine, the desired results, and the economy involved. The effect of all these factors must be considered in the development of the control system.

A Control System

In the development of a control system, it is necessary to set up certain definitions, techniques, dosage curves, control tests, and factors. These are essential to meet all possible variations of chlorine demand by hours or seasons, and with temperature and storms and industrial wastes as well as with pumping schedules and other operating conditions.

Definitions

Chlorine Demand: The parts per million (mg. per liter) of chlorine required to be added as *chlorine water* (1 mg. Cl_2 per ml.) to produce 0.1 p.p.m. of residual chlorine after 15 minutes contact of the chlorine water and sewage.

Residual Chlorine: That chlorine added to water or sewage which is available, after a definite contact time, for reaction with orthotolidine or potassium iodide. It is the surplus of chlorine added which is not required in satisfying the chlorine demand of the liquid chlorinated.

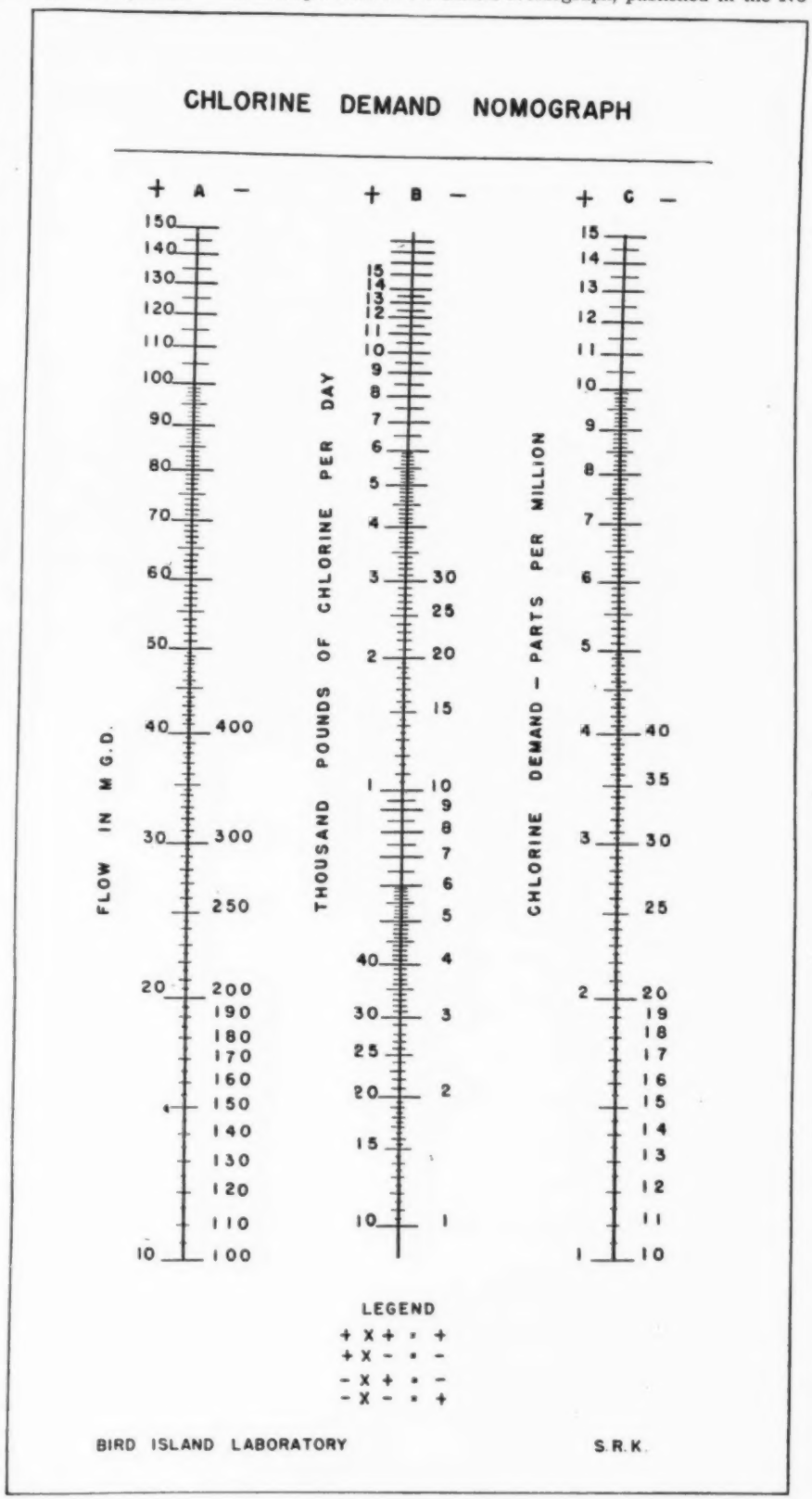
Spot Test: The determination of the residual chlorine in chlorinated liquids by the addition of 3 drops of orthotolidine reagent to 1 ml. of sample on a conventional laboratory spot plate.

Immediate Chlorine Demand (I.C.D.): The parts per million (mg. per liter) of chlorine required to be added as chlorine water (1 mg. Cl_2 per ml.) to produce 0.1 p.p.m. of residual chlorine when a spot test is made on the sewage immediately after the addition of the standard chlorine water. This value is indicated by the abbreviation I.C.D.

Reagent Factor: The factor used to calculate p.p.m. of chlorine demand from the amount of chlorine water added to the sample. This factor is calculated from the size of the sample (in ml.) used for the determination, and the strength of the chlorine water in mg. per ml. Reagent factor × ml. of chlorine water = p.p.m. of chlorine demand (C.D.).

Chlorine Demand Rate per 24 Hours: The feeding rate, in terms of pounds of chlorine added per day, required to satisfy the chlorine demand of any given flow of sewage with a particular chlorine demand, i.e., the rate of feed required in lb./24 hrs. to meet the chlorine requirement for the flow and sewage strength (chlorine demand) existing at any hour.

Chlorine demand rates per day equal p.p.m. of C.D. × flow in m.g.d. × 8.34. This value can be determined directly from the Multiple Chlorine Demand Nomograph, published in the No-



vember, 1940, issue of this magazine[2]. It is an adaptation of a single nomograph for chlorine demand originally developed by Everett C. Handorf[3].

Chlorine Demand in Pounds per m.g.: Lb. per m.g. = p.p.m. of C.D. × 8.34

Dosage Factor: The factor by which the chlorine demand (lb. per m.g.) at any particular hour must be multiplied to determine the chlorine dosage rate (lb. per m.g.) for the following hour.

The use of this factor may be necessary in the control of the chlorine dosage because frequently the time required for collecting the samples and making the chlorine demand test makes it impossible to ascertain the demand until after the sewage represented by the sample has been chlorinated. This factor is affected by the time of day, season of the year (temperature of sewage) and storm flows.

Dosage Rates: The number of pounds of chlorine to be added to each million gallons of sewage pumped during the succeeding period until another adjustment is made.

The Determination of Chlorine Demand

Approximately a 5 pint sample of sewage is collected. All samples should be delivered immediately to the laboratory for analysis. Residual chlorine tests should be made on samples of sewage after chlorination. The chlorine demand is determined on samples, as follows:

(1) *Reagents:* Chlorine water made by passing chlorine gas through distilled water or tap water until 1 ml. contains approximately 1 mg. of chlorine. Standardize by titration with thiosulphate. Orthotolidine indicator solutions as recommended in the committee report on "Control of Chlorination[4]."

(2) *Procedure:* Measure out 5 portions of sewage to be tested, using 200 to 250 ml. samples. To the first of these samples add the standard chlorine water, 0.5 ml. at a time (equivalent to approximately 2 p.p.m. of chlorine) mixing by gentle agitation until a spot plate test, using 3 drops of orthotolidine solution and 1 ml. of the sample, give a detectable yellow color[5], but not necessarily a non-fading color. Call this the immediate chlorine demand (I.C.D.).

Using the I.C.D. as the basis of dosage, add reagent chlorine water to the other flasks in increasing quantities, using increments of 0.2 to 0.5 ml. above the I.C.D. Gently mix the contents of all flasks and allow to stand for exactly 15 minutes. At that time determine the residual chlorine in each flask by a spot test. (It may generally be expected that the I.C.D. is somewhat less than the 15 min. C.D.)

Usually 1 minute is sufficient for the development of maximum color. Use standards made from chlorine water or permanent standards made from copper sulphate and potassium dichromate solutions. These latter must, however, be adjusted to match the hue produced by chlorine water and orthotolidine in a spot plate.

When the maximum color has developed in all spots determine the dosage which has produced 0.1 p.p.m. of residual chlorine or thereabouts. In the absence of standards for comparison, pick the spot with the minimum color. This color is approximately 0.1 p.p.m. In some cases it may be necessary to interpolate in order to determine the amount of chlorine reagent necessary to produce the readable color.

(3) *Calculations:* Calculate the chlorine demand from the amount of chlorine water used and the reagent factor, as illustrated previously. When using 250 ml. of sample; ml. of chlorine solution × mg. of chlorine per ml. × 4 equals p.p.m. chlorine demand (C.D.), or prepared tables may be used for different sized samples and different reagent factors.

For the data records the Chlorine Demand Rate in pounds per 24 hours is determined from the chlorine demand in p.p.m. and the registered sewage flow at the time of the sampling. The Chlorine Demand Nomograph[2] (see cut) is used for this calculation and the resulting value is utilized in weighting the 24 hour average chlorine demand in parts per million.

Directions for Using the Nomograph

In reading the nomograph to determine the chlorine demand or dosage in 1,000 pounds per day from the p.p.m. and the flow in m.g.d., a simple algebraic rule for multiplication must be remembered, viz., plus times plus equals plus, plus times minus equals minus, and vice versa, and minus times minus equals plus. Therefore, if the A+ and C+ scales are used, read on B+, or if A+ and C— are used, read on B—, or if A— and C— scales are used, read B+.

The use of these scales in this manner allows a range of from 1 part per million and 1,500 m.g.d. to 150 p.p.m. and 10 m.g.d. with the thousand pounds per day varying between 0.1 and 1,500. Factors or multiples of 10 extend the range in both directions. By the use of factors or multiples, the readings can always be kept in the area most easily read. A factor of 1,000 will easily convert thousand pounds per day to pounds per day. Scales "A" and "C" can be used for quantities rather than rates per day, in which case Scale "B" reads in quantities rather than rates per day.

The nomograph has other applications than in chlorine application. It may be used to calculate pounds or thousand pounds of solids in sewage, or sludge, from the analysis and the volume, and for other purposes.

This type of nomograph has several advantages, its use is simple, it gives relatively accurate readings, its system and use can be easily taught to routine control, and it eliminates much calculation where the chlorine demand determination is made frequently.

Determination of Chlorine Dosage

After the determination of the chlorine demand on the samples, the results must be translated into operation control. The data available for this use include the following:

a. The 15-minute chlorine demand of the raw sewage.

b. The residual chlorine or chlorine demand (as the case may be) of a sample of sewage after chlorination.

Obviously all of these data represent conditions that have passed and therefore some relation between such data and future hours has to be developed. The average or normal expected relation of the chlorine demand of one hour to the next for raw sewage may be determined from statistical study of the hourly variations in chlorine demand[6]. Inasmuch as these relations vary with seasonal temperatures, it is necessary to develop several series of factors to apply at the different seasons. Typical factors as developed at Buffalo, N. Y.,[2] are listed in Table I which shows the percentage by which the chlorine demand of the previous hour must be multiplied to obtain the chlorine demand for the hour desired. For practical purposes these percentages were rounded off to factors containing one decimal place as shown.

If there were no other factors involved, it would be possible to calculate the *Chlorine Dosage Rate* in pounds per million gallons for the succeeding hours from these factors and the chlorine demand in p.p.m. of the sample of the previous hour. However, it has been found in practice that there is a seasonal empirical factor that must be applied to these calculations. In the winter time it is found that something less than the calculated

TABLE I

FACTORS FOR DETERMINING CHLORINE DEMAND AT ANY HOUR FROM RESULTS OF PREVIOUS HOUR

Season	—Jan., Feb., Mar.—		——April——		——May——		June, July, Aug., Sept.		Oct., Nov., Dec.	
Hour	Per Cent	Factor	Per Cent	Factor	Per Cent	Factor	Per Cent	Factor	Per Cent	Factor
8:00 A.M.	103	1.0	97	1.0	105	1.1	102	1.0	98	1.0
9:00 A.M.	111	1.1	116	1.2	107	1.1	113	1.1	112	1.1
10:00 A.M.	112	1.1	114	1.1	111	1.1	108	1.1	111	1.1
11:00 A.M.	113	1.1	118	1.2	122	1.2	116	1.2	118	1.2
12:00 Noon	102	1.0	111	1.1	110	1.1	103	1.0	104	1.0
1:00 P.M.	100	1.0	98	1.0	88	0.9	105	1.1	100	1.0
2:00 P.M.	98	1.0	98	1.0	97	1.0	99	1.0	100	1.0
3:00 P.M.	102	1.0	100	1.0	98	1.0	101	1.0	103	1.0
4:00 P.M.	106	1.1	98	1.0	109	1.1	100	1.0	100	1.0
5:00 P.M.	100	1.0	106	1.1	97	1.0	100	1.0	103	1.0
6:00 P.M.	96	1.0	92	0.9	98	1.0	97	1.0	99	1.0
7:00 P.M.	96	1.0	100	1.0	100	1.0	100	1.0	96	1.0
8:00 P.M.	92	0.9	96	1.0	98	1.0	97	1.0	95	1.0
9:00 P.M.	100	1.0	89	0.9	95	0.9	95	1.0	97	1.0
10:00 P.M.	94	0.9	95	1.0	98	1.0	94	0.9	94	0.9
11:00 P.M.	104	1.0	95	1.0	100	1.0	100	1.0	102	1.0
12:00 Mid.	94	0.9	97	1.0	96	1.0	95	1.0	97	1.0
1:00 A.M.	98	1.0	97	1.0	96	1.0	102	1.0	98	1.0
2:00 A.M.	95	1.0	100	1.0	98	1.0	98	1.0	97	1.0
3:00 A.M.	95	1.0	100	1.0	96	1.0	96	1.0	97	1.0
4:00 A.M.	92	0.9	94	0.9	93	1.0	93	0.9	93	0.9
5:00 A.M.	97	1.0	94	0.9	93	1.0	94	0.9	100	1.0
6:00 A.M.	97	1.0	90	0.9	97	1.0	94	0.9	95	1.0
7:00 A.M.	103	1.0	111	1.1	103	1.0	102	1.0	96	1.0

chlorine dosage from laboratory tests will satisfy the actual demand of the sewage in the plant and will produce a residual chlorine content in the sewage 15 minutes after dosage. In the summer the reverse is true. Therefore, a series of *Dosage Fac-*

TABLE II

FACTORS FOR DETERMINING CHLORINE DOSAGE

Seasonal Dosage Factors for the Determination of the Chlorine Dosage for Any Hour from the Analysis of a Sample of the Previous Hour

Season Hour	Jan., Feb. and Mar.	April	May and Dec.	June and Nov.	July and Oct.	Aug. and Sept.
8:00 A.M.	0.9	0.9	1.0	1.1	1.2	1.3
9:00 A.M.	1.0	1.0	1.1	1.1	1.2	1.3
10:00 A.M.	1.0	1.1	1.2	1.2	1.3	1.4
11:00 A.M.	1.0	1.1	1.0	1.2	1.3	1.4
12:00 Noon	0.9	1.0	0.9	1.1	1.2	1.3
1:00 P.M.	0.9	0.9	0.9	1.0	1.1	1.2
2:00 P.M.	0.8	0.8	0.9	1.0	1.1	1.2
3:00 P.M.	0.7	0.8	0.9	1.0	1.1	1.2
4:00 P.M.	0.7	0.8	0.9	1.0	1.1	1.2
5:00 P.M.	0.7	0.8	0.9	1.0	1.1	1.2
6:00 P.M.	0.7	0.8	0.9	1.0	1.1	1.2
7:00 P.M.	0.7	0.8	0.9	1.0	1.1	1.2
8:00 P.M.	0.7	0.8	0.9	1.0	1.1	1.2
9:00 P.M.	0.6	0.7	0.8	0.9	1.0	1.1
10:00 P.M.	0.6	0.7	0.8	0.9	1.0	1.1
11:00 P.M.	0.6	0.7	0.8	0.9	1.0	1.1
12:00 Mid.	0.5	0.6	0.7	0.8	0.9	1.0
1:00 A.M.	0.5	0.6	0.7	0.8	0.9	1.0
2:00 A.M.	0.5	0.6	0.7	0.8	0.9	1.0
3:00 A.M.	0.5	0.6	0.7	0.8	0.9	1.0
4:00 A.M.	0.5	0.6	0.7	0.8	0.9	1.0
5:00 A.M.	0.5	0.6	0.7	0.8	0.9	1.0
6:00 A.M.	0.5	0.6	0.7	0.8	0.9	1.0
7:00 A.M.	0.7	0.8	0.9	1.0	1.1	1.2

tors to fit operating conditions were developed for the various seasons as shown in Table II, for Buffalo.

Having determined the demand of the raw sewage in p.p.m., then by the use of the various tables the *Dosage Rate* in pounds per million gallons can be calculated for the succeeding hour. The value multiplied by the flow gives the setting for the chlorinators accordingly for the succeeding hour.

As might be expected, there are exceptions which will not fall into this regular routine. The tests on the chlorinated effluent samples are an aid in checking operation and exceptional conditions. Any continued over-or-under-chlorination calls for adjustment of the dosage factor. Likewise, the test on the effluent may indicate a dosage too low to produce effective disinfection[7].

Special Conditions Affecting Chlorine Control

To meet the special conditions which arise by virtue of any one or more of a number of factors including storms, pumping schedules, and others, special rules must be developed from practical and theoretical considerations.

These rules must consider such items as, over or under-dosages, sudden changes in rate of flow because of changing pumping schedules, desired disinfection of storm flows, abnormal chlorine demands caused by industrial wastes, false end-points, or effect of digestion tank supernatant liquor.

Maintenance of Chlorination Equipment

Mechanical difficulties with chlorinators may include some unusual occurrences, repairs, or cleaning.

For example, during the summer months, insects prevalent in the locality, may add to the difficulties of operation when the insects alight in the water of the bell jar tray and are drawn into the apparatus plugging the water lines. Uneven pressure exerted on the rim of the jar by the stops being too tight may cause strain, and sudden differences in temperature between gas and water contribute to the cracking, but greater care and attention to these details will reduce this breakage.

Accumulation of chlorine "taffy" in the evaporators may result in sudden discharge into the bell jars at times. Some of this material is high in ferric chloride and the fact that pipe lines have been found to contain ferric chloride indicates a possible reverse migration of water. This migration may occur due to back pressure in idle chlorinators.

It has been observed that chlorine solution backing up into idle machines from the discharge lines occurred apparently because of chipping of the glass ball check valves in the lines from the individual chlorinators. The corrosive solution causes disintegration of the chlorine needle valve stems, thereby requiring more replacement of this item than any other. It is, therefore, expedient to keep idle machines operating under a slight vacuum, and frequently to drain all tubes and valve chambers to insure removal of the corrosive solution. Pressure reducing diaphragms have had to be replaced because they developed fine pin holes, possibly due to corrosion induced by the suspected reverse migration of water.

Cleaning of various items may be by several methods. Carbon tetrachloride or acetone to clean bell jars of "gum"; steam followed by hot air or acetone to clean iron pipe lines carrying liquid chlorine.

In summarizing, it should be pointed out that the details of this method of dosage control are subject to revision as chemical, bacteriological, and operating data are obtained, but the fact that the disinfection results[8] have been most satisfactory indicates that the principles of the system are basically sound.

References

1. A. E. Griffin and G. A. Campbell, "Problems & Progress in the Chlorination of Sewage," Sewage Works Journal, 12, 307-20 (1940).
2. G. E. Symons and S. R. Kin, "A Multiple Nomograph for Chlorine Demand Determinations," Water Wks. & Sew., 87, 547-48 (1940).
3. Everette C. Handorf, Water Works Engineering, Jan. 10, 1934.
4. A.W.W.A. Committee Report, "Control of Chlorination," J.A.W.W.A., 35, 1315-28 (1943).
5. G. E. Symons, "A Modification of the Chlorine Demand Test & Orthotolidine Test for Residual Chlorine in Sewage," Sew. Wks. Jour., 9, 569-78 (1937).
6. G. E. Symons, R. W. Simpson and S. R. Kin, "Variations in the Chlorine Demand of Buffalo Sewage," Sewage Wks. Journ. 13, 249-64 (1941).
7. G. E. Symons, R. W. Simpson and Wm. L. Torrey, "Reduction of Bacteria in Sewage by Chlorination," Water Wks. & Sew., 85, 983-91 (1938).
8. G. E. Symons and R. W. Simpson, "Disinfection of Sewage by Chlorination." Paper presented before the Spring Meeting of the N. Y. State Sewage Wks. Ass'n at Niagara Falls, N. Y., on June 19, 1941.

KILLING ROOTS IN SEWERS WITH COPPER SULPHATE

By J. W. McAMIS

Superintendent Water Works and Sewerage, Greenville, Tenn.

Roots give a great deal of trouble in the smaller sewers, by causing stoppages wherever they may happen to find an entrance into the pipes carrying domestic sewage.

For four or five years now we have been using copper sulphate to combat this trouble.

We have a man whose duty it is to visit each manhole in the system at least once each month, looking for stoppages. He carries along on these trips a small bag or bucket of copper sulphate and drops a small handful of crystals down into the flowing sewage wherever he finds that the stoppage is downstream.

After a reasonable amount of experience in this work a man can tell pretty well where trouble is to be expected in the near future, by the nature of the flow of the sewage and by the conditions in the bottom of the manhole.

In cases where stoppage is due to roots, sewage will back up into the next manhole above during periods of greatest flow during the day and will recede during periods of low flows. This condition may exist for days or possibly weeks before the sewage begins to overflow the top of the manhole and run into the street. By throwing in the copper sulphate crystals *while the sewage is still flowing*, a sufficient concentration of the poison will usually reach the seat of the trouble to eliminate it before the stoppage is complete.

At Greenville, we have the same man doing this work that looks after the disposal plants and he tells me that he can predict almost exactly when the balls of roots will turn loose and come down to the treatment plant following the copper treatment.

Since we have been using this scheme it is a rare day when we have to send out a truck with sewer-rods and other equipment to open up a stopped sewer.

Regarding the exact quantity of the sulphate required for good results, I have attempted no determination of the necessary concentration of copper sulphate. However, it is my opinion that the length of the contact period is a more important factor than the actual concentration of the copper sulphate. To illustrate; the ideal condition seems to be where a small flow of sewage, say two to five g.p.m., is just trickling through a mass of roots. In a case like this a small handful of the chemical applied in the manhole just upstream from the stoppage will do the trick.

If the flow is greater, as determined from looking in the manhole just below the stoppage, greater quantities and possibly repeated applications would be necessary. If it is kept in mind that it is time of contact that is important, rather than the amount of copper sulphate, no trouble should be experienced in carrying out this operation.

Another important point to remember is that it is useless to apply the copper sulphate in a sewer that is completely stopped, for unless there is at least a small flow of sewage through the obstruction there is no chance for contact between the roots and the copper solution. Sewer rods would be the only remedy here—at least to start some flow through and allow the copper to reach the roots. (Since it is only necessary to kill the small root which enters the sewer, and not the great mass of roots branching from it, the important factor is that of reaching the feeder root with the killing chemical. Then, the flow pulling on the large heavy "brush," causes the weakened base root to break. Prechlorination of sewage has been found to produce the same results on root infected sewers but is not so simply applied as the copper treatment.—Ed.

AN INEXPENSIVE HYPO-CHLORINATOR

Adaptable Also to Feeding Other Chemicals in Water and Sewage Treatment

By J. R. SNELL
Sanitary Engineer
Chief, Water and Sanitation Section, Hdqt. 1st Service Command
Boston, Mass.

The constant feed regulator (see accompanying sketch) consists of a simple constant level float, and an orifice which can be raised or lowered to adjust the rate of flow as desired. A swivel arm and clamp hold the orifice firmly in position.

The float rising against the glass tube keeps the level of chlorine solution at a constant level in the feed regulator and, therefore, the flow through the orifice is constant and is not dependent on the height of the solution in the feeding barrel.

The materials employed in the constant feed regulator can be obtained from almost any chemical or medical supply company, while the feed barrel is a 50-gallon cooper's barrel and can be purchased from any barrel dealer.

The barrel should be thoroughly impregnated and coated with paraffin to protect it against the highly corrosive chlorine solution. The barrel may last over a year or have to be discarded in less than three months, depending on the thoroughness with which paraffin has been applied. A blowtorch is valuable in the impregnation process, while a paint brush is helpful on the final coating procedure.

If the builder has had any experience in cutting and bending glass tubing, he could buy the required rough materials and do the work himself. However, better results, at very little cost, can be had by getting the work done by a professional glass-blower. The apparatus, including all glassware and rubber (without stand) was made for $1.82 each when a dozen were ordered at one time. The itemized cost of the whole chlorinator is as follows:

Barrel	$2.00
Apparatus	1.80
Supports	1.00
Paraffin	.20
	$5.00

The stoppers used are standard rubber No. 4 and 8. The one on the top of the float has to be rubbed smooth with a fine emery stone, while the large one above this should have a triangular notch cut in its side to act as a vent.

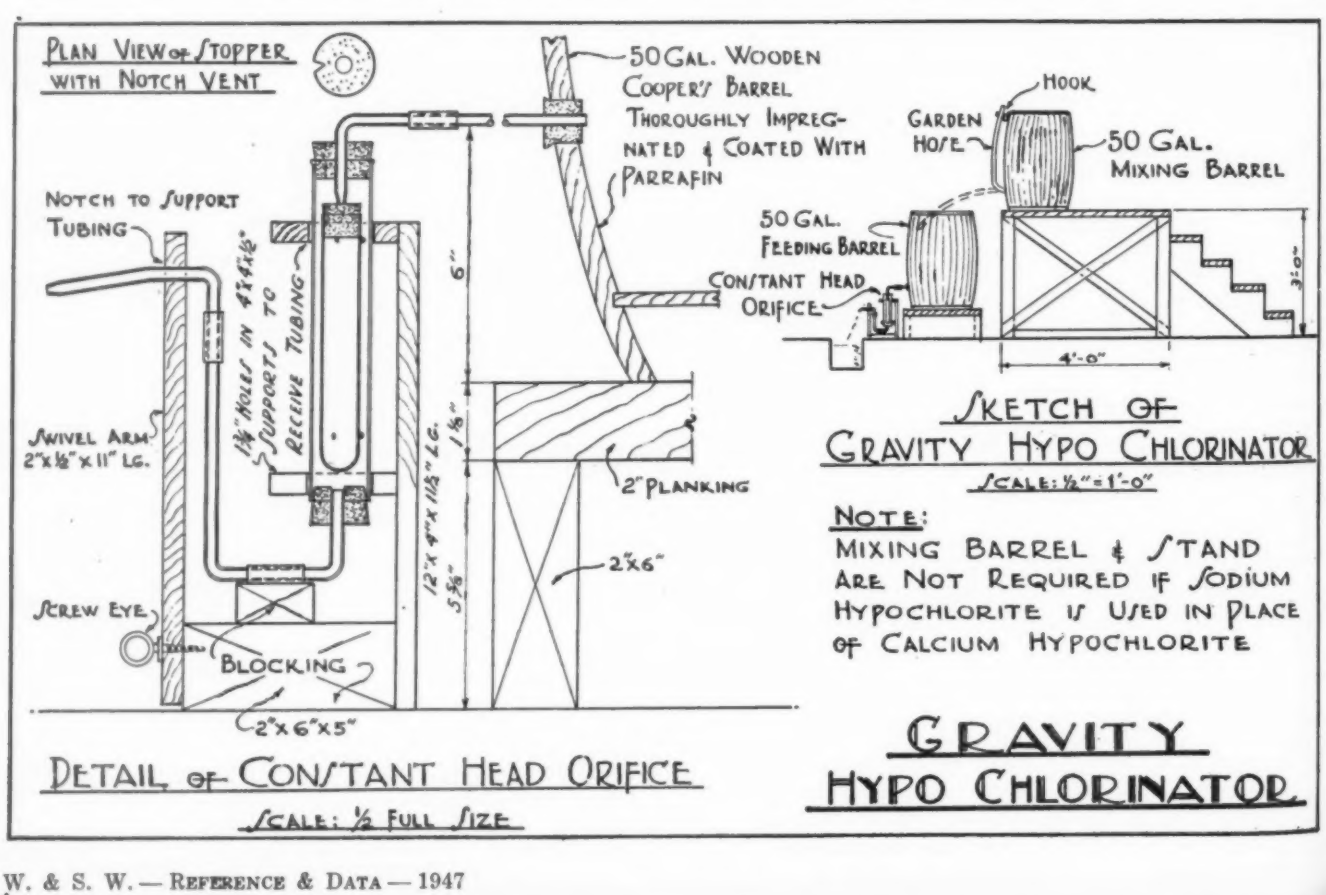
Should calcium hypochlorite be employed in place of sodium hypochlorite, a second cooper's barrel is required for mixing. If this precaution is not taken, sludge or scum will soon clog the apparatus. A three-foot-high support for this mixing barrel facilitates operation. The quantity of calcium hypochlorite should be measured out daily, stirred into the barrel full of water for ten minutes, and then allowed to settle for at least two hours before being drawn over into the feeding barrel. Accumulated scum and sludge has no chlorine value and should be cleaned out of the mixing barrel periodically and never allowed to be present in the feeding barrel.

The rate of flow can be adjusted from 10 to 100 gal. per day by adjusting the height of the orifice by rotating it sidewise. It is recommended that the flow be set and maintained at 30 gal. per 24 hours. This is equal to ½ pint (8 fluid oz.) in three minutes. The quantity of chlorine dosed had best be adjusted by varying the strength of the solution.

In using calcium hypochlorite difficulty may be had if solutions stronger than 1 per cent are used, but sodium hypochlorite may be used at any strength up to that provided by the manufacturer, which is generally 10, 12½ or 14 per cent.

The large soft glass tubing is 37 mm. (1½ in.), while the small soft glass tubing and the neoprene tubing are 8 mm. Neoprene tubing, although more expensive than natural rubber, is much more resistant to the corrosive action of chlorine. The test tube is a standard 6x1-in. diameter and has three 3/16-in. glass projections, fused on top and bottom to act as a guide and prevent sticking. The openings in the orifice, and the opening above the float, should be drawn out to about 2 and 4 mm. in diameter respectively. The latter must be ground flat with a fine emery stone to insure positive closure against the float stopper. The correct measurements for the length of tubing and bends can be obtained by scaling from the sketch. The support shown can be built from scrap lumber in a few minutes.

It is important that the float assembly be kept vertical. The rubber stoppers must be pushed in firmly and evenly or the float, on rising, will not produce satisfactory closure. If it is not indoors, it should be further protected by building a box for it. The solution water supply must be clean and free from foreign matter which may clog the apparatus.



SEWAGE PLANT RECORDS AND OPERATING REPORTS*

By L. S. MORGAN
District Engineer, Pennsylvania Department of Health

SEWAGE treatment plants are constructed and operated for the specific purposes of (1) eliminating stream pollution and (2) protecting the public health. Various degrees of treatment of sewage are necessary to control pollution of streams to the extent required to protect the waters thereof, which are subsequently used for sources of public and industrial water supplies, for bathing places and other recreation and for the support of animal, fish and other aquatic life.

Satisfactory operation of the sewage treatment works to accomplish these desired purposes will generally be reflected in the plant records and operating reports maintained by the plant operators. It is essential that proper plant records and operating reports be maintained for the following reasons:

1. To indicate to the plant operator and responsible officials that the individual units of the plant and the plant as a whole are maintained and operated so as to produce the desired results.
2. To serve as the basis of reports to proper responsible officials.
3. To warn the operator of circumstances which may produce troubles in operation, with resulting lowered efficiency.
4. To serve as a guide for future operations in the light of past experience.
5. To serve as a permanent record of plant performance for use as legal evidence.
6. For reference as a basis for determining future treatment requirements.

Types of Operating Records

The required type of operation records will depend largely upon the degree of treatment provided in the plant, the type of units installed and the personnel and facilities available for plant control work. As a general rule, these records will consist of charts which are produced from operating mechanisms installed at the time the plant was constructed or added thereafter, and those which are made up by the plant operators. This discussion will deal with the latter group.

Operation report forms should be provided for the use of the plant operator at the time the plant is constructed, and these forms should be made up for the individual plant under consideration. While it is true that plants having the same degree of treatment and the same types of units can use similar operation reports, some variations may be necessary in the type of data to be recorded.

In addition to the information to be specifically recorded on the standard report form, the plant operator should maintain a daily log book which should contain certain notations on circumstances encountered in plant operation and control which are not otherwise recorded, and thus serve as a record of unusual occurrences. Forms for recording the information to be kept as an operating record should be printed and preferably made up in tablet form so that multiple copies can be produced at the time the original is made. Generally, the Pennsylvania Department of Health requires sewage works operation reports to be submitted at weekly intervals, such reports containing the daily records of operation and the results of such tests and analyses as are deemed necessary for the proper control of the operation of the plant.

All operation report forms should contain certain essential information. This would include the day of the week and date, the general weather conditions, the daily temperature and preferably daily precipitation. The report should also show the total sewage flow and the sewage temperature; the particular plant units in and out of service; the amounts of chemicals used at the designated points of application; the volumes of screenings, scum and sludge removed from each unit or transferred from one unit to another, the final disposition of these materials; the dates of cleaning various units; the depth of sludge accumulated in tanks, introduced onto beds or other drying facilities and removed therefrom; and it should include a space for general remarks in which can be placed specific information concerning the condition and use of units in the plant, prevalence of odors in the vicinity of the plant, condition of receiving body of water above and below the point of discharge of the plant effluent, and other pertinent data.

No operation report is complete without the results of physical and chemical determinations made of samples of the sewage as it enters the plant and passes through successive steps in treatment, as well as a record of the removals obtained by each successive step. The minimum determinations which should be recorded as a part of the operation report include tests for settleable solids, pH values of sewage and sludge, chlorine residual and relative stability, with the latter test being supplemented by 5-day B.O.D. determinations where adequate facilities are available.

An index map and flow diagram placed as a permanent record on the report form is a material aid in designating the various units of the plant by number and in the interpretation of the detailed data reported.

Operation Data

It is rather difficult to outline in general the specific information which should be included on each operation report because of the variation in the type of units and the degree of treatment provided for individual sewage treatment plants. The following summarized data, however, will give each plant operator an indication of the type of information he should record on his daily log and on his operation report, in accordance with the more common types of units found in sewage treatment plants:

Sewage Pumping Station:
1. Pumps in operation
   a. Hours operated
2. Times trash screens cleaned
   a. Quantities of trash removed

Weather Conditions:
1. Notation of weather prevailing
2. Air temperature
3. Daily precipitation

Raw Sewage:
1. Total daily flow
   a. Minimum flow rate
   b. Maximum flow rate

Grit Chambers:
1. Units in service
2. Amount of material removed daily
3. Disposition of grit
4. For mechanically cleaned chambers, hours mechanism operated

Screen Chambers:
1. Units in service
2. Amounts of material removed
3. For mechanically cleaned screens, hours mechanism operated
4. Disposition of screenings

Sedimentation Tanks:
1. Septic tanks:
   a. Tanks in use
   b. Period in service
   c. Depth of sludge and scum
   d. Scum broken up
   e. Volume of sludge and scum withdrawn
   f. Disposition of sludge
2. Mechanically cleaned tanks:
   a. Units in service
   b. Hours mechanism operated
   c. Volumes of sludge and scum removed
   d. Disposition of sludge and scum
3. Imhoff tanks:
   a. Units in service
   b. Volume scum removed
   c. Cleaning of septum walls and slots
   d. Disposition of scum

Sludge Digestion Tanks:
1. Imhoff:
   a. Thickness of gas vent scum
   b. Depth of sludge
   c. Scum broken up in gas vents
   d. Amount of lime added when needed
   e. Volume of sludge withdrawn
   f. Disposition of scum and sludge
2. Separate digestion:
   a. Volume of sludge added
   b. Volume supernatant liquor withdrawn
   c. Hours agitation equipment operated
   d. Volume of water circulated
   e. Temperature heating water and return
   f. Volume of sludge removed
   g. Volume of sludge transferred
   h. Amount of lime added
   i. Sludge temperature
   j. Volume of gas produced
      (1) Volume of gas used
      (2) Volume of gas wasted
   k. Depths of sludge and scum in tank

Dosing Chambers:
1. Number of doses
2. Dosing equipment and tank cleaned

Trickling Filters:
1. Number of units in service
2. Inspection of surface media to detect clogging
3. Method of treatment to prevent pooling
4. Method of treatment for control of filter flies
5. Distribution system
   a. Number of nozzles cleaned
   b. Number of orifices opened
   c. Flushing and cleaning distributor lines

*Presented at Lecture-Laboratory Course on Sewage Treatment and Disposal, given by Pennsylvania Sewage Works Assn., at St. Joseph's College, Philadelphia, Pa., May, 1945, and reprinted from *Sew. Wks. Jour.* by permission of the F.S.W.A.

6. Underdrain system.
   a. Flushing and cleaning

Activated Sludge:
1. Number of tanks in service
2. Volume of air applied
3. Volume return activated sludge
4. Volume of waste activated sludge
5. Air diffusers cleaned
6. Disposition waste activated sludge
7. Amounts and kinds of chemicals used for conditioning activated sludge

Final Settling Tanks:
1. Units in service
2. Depth of sludge in tanks
3. Tanks cleaned
4. Volume of sludge removed
5. Disposition of sludge
6. For mechanically cleaned tanks, hours mechanism operated

Intermittent Sand Filters:
1. Number of units in service
2. Depth of dosage applied to beds
3. Number of doses
4. Number of beds cleaned
5. Volume of material removed
6. Disposition of material removed
7. Depth sand replaced

Sludge Drying:
1. Sand beds:
   a. Number of beds in service
   b. Depth of dosage and volume sludge applied
   c. Period necessary for drying
   d. Depth and volume of sludge removed
   e. Drying beds cleaned
   f. Disposition of sludge
   g. Depth sand replaced
2. Vacuum filters:
   a. Number of units in service
   b. Hours operated
   c. Volume of sludge filtered
   d. Amounts of conditioning chemicals added
   e. Filters cleaned
   f. Quantity of sludge cake produced

Chlorination:
1. Weight of chlorine tanks daily
2. Amounts of chlorine applied per day at designated points of application
3. Rates of chlorine application in lb. per mg. or ppm.

The terms used for indicating the volumes of material removed in various processes will generally be in cubic feet where the material is removed in a fairly dry state, such as from trash screens, grit chambers, screen chambers and detritor tanks and skimming mechanisms for sludge removal and drying facilities. For sewage flows the results should be given in terms of gallons for small plants, thousands of gallons for intermediate size plants and millions of gallons for large plants. For miscellaneous items such as temperature, rainfall, gas produced, etc., the conventional terms generally applied to the specific items should be used. All entries for miscellaneous data not included as daily operational procedure should be made opposite the dates on which such observations or operations are made.

Analytical Determinations

Such physical and chemical determinations as are necessary for the particular plant should be made at sufficiently frequent intervals to indicate that the various processes of treatment and the plant as a whole are functioning in a proper manner.

Selection of the proper determinations to be made will depend on the type of processes involved, the degree of treatment provided and facilities available, and the frequency of the determinations will depend on the number of operating and laboratory personnel employed.

It is difficult to set forth the kind and frequency of analytical tests to be made at each particular plant. The following summary will, however, give the minimum determinations which should be made for proper plant control for all sewage treatment plants, the additional desirable determinations which should be made where facilities and personnel are available, and other determinations necessary or desirable for special treatment processes and for special conditions.

Determinations of pH should be made of the raw sewage daily, the sludge in the digestion tanks at least semi-monthly, the supernatant liquor from the separate sludge digestion tanks at least semi-weekly, and of the raw and conditioned sludge where it is chemically treated prior to filtering, daily.

Settleable solids determinations should be made daily of the raw sewage, the primary effluent, the secondary effluent and of the final effluent, and the per cent removals noted. Where facilities and personnel are available, the determination for settleable solids should be supplemented by the determination of suspended solids.

Methylene blue determinations of relative stability should be made daily where possible, but at least twice weekly, of the effluents from trickling filters, intermittent sand filters and activated sludge processes. Where personnel and facilities are available, the relative stability tests should be replaced by 5-day B.O.D. determinations made at the same frequency but in addition made of the raw sewage and of the primary effluent.

Residual chlorine determinations of the disinfected effluents should be made at least daily.

Where separate sludge digestion is employed or where better control is desired of digestion and sludge drying processes, total and volatile solids contents of the raw, digested and dried sludges should be determined. Volatile acids determinations may be helpful in control of heavily loaded digesters.

Where the activated sludge process of treatment is employed, tests for dissolved oxygen should be made of the sewage in the aeration and final settling tanks, as well as mixed liquor settleability tests. The suspended solids content should also be determined of the mixed liquor and of the return activated sludge.

Where the sewage is discharged into streams used as sources of public water supply or for bathing or other recreational purposes below the point of discharge and in close proximity thereto, bacterial tests of the effluent should be made.

Other desirable tests, for more complete control of operation and for additional information concerning the efficiency of treatment, include dissolved oxygen, free ammonia, nitrites, nitrates, organic nitrogen, chlorides, chlorine demand and oxygen consumed.

Special determinations are also necessary at times if industrial wastes, which are not normally present in the raw sewage, are suspected and if interference with treatment efficiencies is being experienced.

Sampling

The results of analytical determinations included in the operation report can only represent true conditions if the samples collected are representative of the sewage flow and the determinations are made in accordance with accepted standard practice.

It is best to collect individual samples at definite intervals, and to combine these individual portions into a composite sample for analysis. Daily composite samples can be made up from individual samples collected over 12- or 24-hr. periods, and weekly composite samples can be made from composite daily samples. If at all possible, the individual samples should be combined into the composite sample in volumes proportional to the volumes of flow. The analyses of composite samples will be much more representative of conditions at the plant than results obtained from mere "catch" or "grab" samples.

If personnel is not available to permit the collection and compositing of individual samples over 12- to 24-hr. periods, then a composite sample might be made covering a shorter period, provided that such period is selected to coincide with the general prevailing periods of greatest sewage load.

Care should be taken in collecting sewage samples to use wide-mouthed sampling containers. In making composite samples definite intervals for the collection of the individual portions that make up the composite sample should be established and followed. If a short period of compositing is used, individual samples should be collected at least every half-hour, and if a longer period is used, individual samples should be collected at least every hour.

The manual "Standard Methods of Water and Sewage Analysis" should be followed closely in all laboratory procedures.

Miscellaneous Records

Permanent records should also be kept of the power consumption within the plant by the taking of daily meter readings, with separate readings of power consumption for special processes.

Regular checks should be made to determine the conditions of all mechanical and electrical equipment in the plant, and notations made in the daily log of any replacements or repairs made to such equipment, and of all maintenance done in connection therewith.

Where records are made of such things as air temperature, rainfall, time of emptying and filling tanks and other related matters, they should be made at a stated time each day.

No plant records are complete without a detailed record of the costs of operation. In addition to the usual fixed charges, the plant operator should maintain a complete record of the costs of materials and chemicals used for maintenance and operation of the plant, cost of power purchased, cost of equipment replaced and cost of additional labor employed.

If adequate and satisfactory weekly or monthly records are maintained, then annual operation and cost reports can be readily made up in a convenient manner.

Use of Operation Reports

Records maintained just for the sake of having them are of little value to the plant operator or to the officials responsible for the supervision of the treatment works. They should be referred to frequently by the plant operator and should be used as yard-sticks for measuring the efficiency of the plant, for indicating changes in operation and treatment methods to secure better plant performance, and to show the need for additions or enlargements to the plant, or the need for additional treatment.

USE OF CHARTS IN THE ANALYSIS OF SEWAGE OPERATION*

By W. Vincent Barry
City Engineer, New Haven, Conn.

THE skeptic and the novice may say, "Why charts?" It is a vagary of human nature that the mind can best assimilate statistical or numerical data which are graphically represented. If this statement be doubted, one may look about in his daily routine; the local newspaper, the weekly or monthly magazine, the technical publication and promotional pamphlet, all resort to the graphic sketch in their desire to present most efficaciously their pertinent data to their clientele. Whether this be an inheritance from our stone-age ancestors or otherwise, it is, nevertheless, a recognized trait of man's reasoning.

The maintenance of records of the operation of a sewage treatment plant is of fundamental importance. Very often the daily and monthly reports are casually examined, and unless some out-of-line notation is apparent these records are filed away or pigeon-holed. It occurred to the writer early in 1942 that if such records were properly coordinated in a graphical manner, conclusions might be reached which could prove most valuable in attaining the desired objectives, viz., the economical and efficient performance of the disposal plant. Accordingly, the accompanying charts and sketches are presented as examples.

It should be borne in mind that these charts are illustrations of what can be shown and are not intended to be dogmatic. As local conditions vary, charts should be designed in such a manner as to show what is deemed essential for the individual community. Thus, these charts are intended only as models or guides. In obtaining records, accuracy is of the utmost importance. This means accurate sampling, accurate measuring, accurate recording, and accurate plotting. Unless accuracy is adhered to, records, charts and reports become meaningless. At this point it is worthy of mention that "composite" samples are considered to be most representative. Great care must be exercised in the taking of samples.

A close scrutiny of plant records may be used to determine if the character of sewage departs from its normal consistency. If this occurs, the location of the contributing agency affecting the normal operation of a treatment plant may be determined and recommendations adopted to lessen or remove objectional elements. For example, it was found that a chlorine residual in the effluent of one of the New Haven plants could not be maintained during certain periods except by abnormal dosage. By tracing back through the mains it was ascertained that one of the dye plants was discharging a greatly increased quantity of waste water, containing dye ingredients, into the sewage. This excess was due principally to an increase in operation of the dye plant from eight hours to 24 hours, necessitated by war emergency requirements. As this discharge was intermittent and in large quantities, it was determined that by the construction of two storage tanks, the discharge could be made continuous and in smaller quantities so as to minimize the chlorine dosage and thus obtain a satisfactory residual.

By use of charts it is possible to predict within a reasonable degree what quantity of sludge, gas or sludge cake may be obtained within a certain period, which should be of considerable advantage to the operator at critical times. By the use of similar charts, a progressive and over-all picture is visible, and thus operation can be substantiated.

New Haven Treatment

In the operation of a sewage treatment plant, the ideal, viz., the utmost efficiency of every component part, is impossible of attainment. What then should be considered as satisfactory performance? As this paper is a review of actual experience, the writer must confine himself to primary treatment only. The main factors in this type of treatment at New Haven are:

1. Removal of suspended solids.
2. (a) Digestion, if sewage is not sterile, or (b) temporary storage to render sludge more gelatinous or thickened.
3. Chemical treatment prior to vacuum filtration.
4. Incineration.
5. Removal or use of ashes.

Reviewing these steps, it would seem that the highest percentage of solids removal should be the aim, but as the detention period is one of the main factors in this reduction, a detention period beyond an efficient removal is undesirable. For instance, more suspended solids can be removed from sewage in a 4-hour period than in a 2-hour period. But more solids are removed in the first thirty minutes than in the last thirty. As detention period is governed by capacity of settling tanks, de-

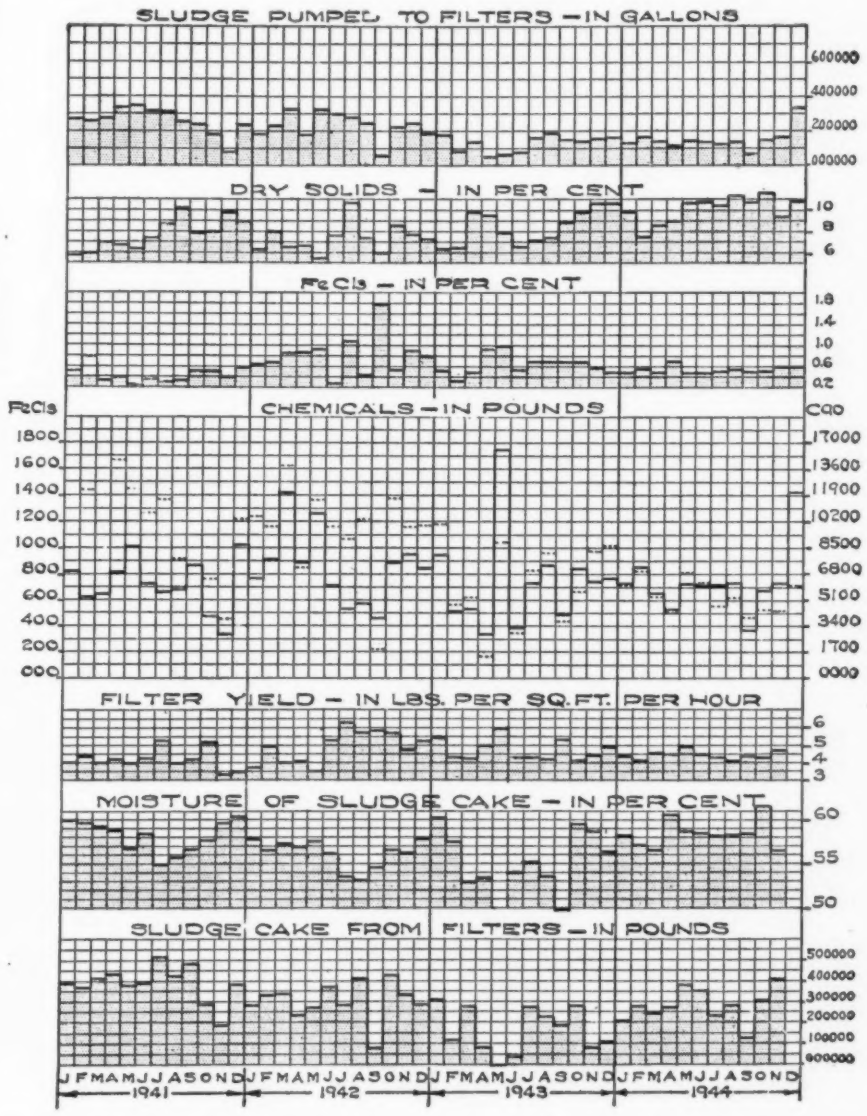


Fig. 1.—Chart of Sludge Conditioning and Dewatering Data at East Street Sewage Treatment Plant, New Haven, Conn.

*From *Sew. Wks. Jour.*, Sept., 1945. Reprinted by permission of the Fed. Sew. Wks. Assns.

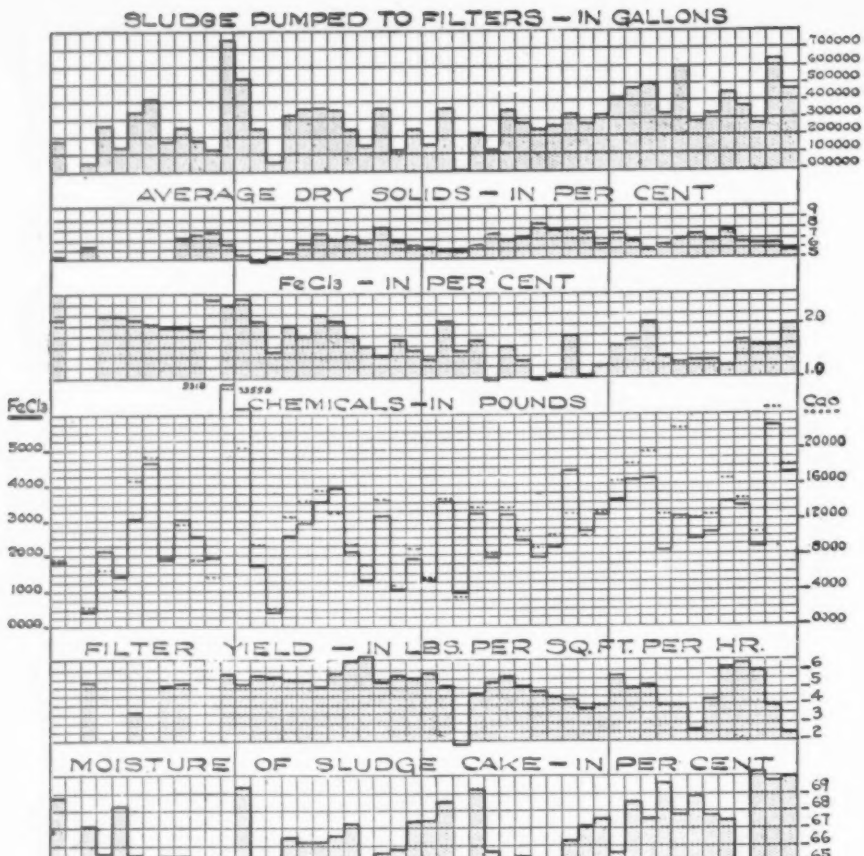

SLUDGE PUMPED TO FILTERS — IN GALLONS
AVERAGE DRY SOLIDS — IN PER CENT
FeCl3 — IN PER CENT
CHEMICALS — IN POUNDS
FeCl3
CaO
FILTER YIELD — IN LBS. PER SQ. FT. PER HR.
MOISTURE OF SLUDGE CAKE — IN PER CENT
SLUDGE CAKE FROM FILTER — IN POUNDS
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1941
1942
1943
1944

Fig. 2.—Chart of Sludge Conditioning and Dewatering Data at Boulevard Sewage Treatment Plant, New Haven, Conn.

tention beyond an efficient period would be uneconomical, as larger tanks occupying more area and containing additional mechanical equipment would be required. This would exact a greater initial investment and also increase the operating and maintenance costs. Therefore, the removal of such quantity of solids as is compatible with the designed detention should be maintained. At the plant using incineration (where no digesters are present), it can be observed that the higher the percentage of dry solids in the sludge removed from the thickening tanks, the smaller the percentage of chemical agents required to produce conditioning of sludge.

As use of these chemicals, particularly ferric chloride, constitutes a large proportion of the cost, their addition should be held to a minimum. Thus, it is necessary to determine from experience an efficient relationship between length of settlement and amount of chemicals. In a plant using incineration after digestion, it is equally true that the amount of chemicals to be added to digested sludge is governed by the amount of dry solids therein. Therefore, in most plants, sludge should be thoroughly digested for the economical conditioning mentioned above.

Sludge Dewatering

Proceeding to the preparation of digested sludge or undigested (raw) sludge for filtration, utmost care must be exercised in the laboratory for the determination of the amount of chemicals to be added. If, in addition to ferric chloride, lime is to be added as a thickener, the proper quantitative ratio between these two should be determined to the end that an economical relationship be established. That there can be and is a wide divergence in the proportion is evidenced in Figs. 1 and 2; the ratio at the East Street plant being 1 pound of ferric chloride to 8½ pounds of lime (CaO) and at the Boulevard plant the ratio is 1 to 4, similarly.

Filter cake yield also has an important bearing in the efficient operation of the plant. A yield of four pounds per square foot per hour is considered satisfactory. It should be borne in mind that too much reduction in moisture content of the cake is uneconomical, as the incinerator is designed to burn sludge cake of an established moisture content, and too much deviation from this value will result in inefficient consumption or uneconomical usage of chemicals.

For example, if the designed operating efficiency of an incinerator is cremation of sludge cake having a moisture content of 70 per cent, then attempts should be made to approximate this figure. Less moisture content means that the optimum amounts of conditioning chemicals have been exceeded, which naturally results in increasing the cost of conditioning sludge cake. On the other side, greater moisture content than 70 per cent means excesses in quantity of fuel oil in the upper hearths of the furnace, thus increasing cost of incineration.

Preparation of Charts

In the preparation of charts, it is the writer's belief that interdependent records should be plotted on one sheet insofar as practicable. For instance, percentage of suspended solids removed, time of detention, total sewage flow and maximum daily flow are closely allied, and thus should be recorded on the same page (Fig. 3). On another sheet (Fig. 2), total sludge (either digested or "raw") to be conditioned is shown together with percentage of dry solids therein, total amounts of chemicals added and percentage of ferric chloride. In addition, filter yield and percentage of moisture of sludge cake are included as is the total amount of sludge cake.

In the plotting of amounts of chemicals applied, the graduations used should be designed so as to show the established operating ratio. On one side of this scale, the values indicated are multiple components of those on the opposite side, as derived from operation. As an illustration, in Fig. 2 showing the pounds of chemicals used, the graduations on the right side have a numerical value of four times those on the left. Thus, in plotting quantities of chemicals used in any period, the observer can tell at a glance whether or not the proper ratio was in use in conditioning and if not, the chemical used in excess is very much in evidence. Close attention to this chart can result in economy with respect to chemicals applied.

Show More Than One Year

These charts are particularly significant in that they show statistics from the very start of operation of the plants; Boulevard plant was placed in operation late in 1940 and East Street plant early in 1941. Thus it can be seen how erratic performance has been leveled off, and a more regular routine developed. In the plotting of these charts, a 4-year record was established for just this reason. For the continuous record, a charting period of three years would seem to be the minimum desideratum.

Irrespective of the adopted term of years, the recorded performance of the year previous should be plotted as this will afford a comparative medium to determine monthly efficiency. Any great divergence may thus be noted, and by reference to previous years such variance may be reconciled. Where a number of years are plotted on a single sheet (Fig. 4), comparative figures for a designated month in each year may be more readily ascertained by the use of a template. By application of this template to the record sheet, the figures for the desired month in each year will alone be visible.

Fig. 4 is mute evidence of the fallacy of the use of "cost per million gallons" as the sole measure of plant efficiency. While there is much less annual consumption of power at East Street and somewhat lower

use of chemicals, the unit cost is greater than at the Boulevard plant. On the surface this would seem inconsistent, particularly as there is less mechanical equipment at the East Street plant. More manual operation is required, however, at East Street and eleven men are employed there, and while the same number of employees are in attendance at Boulevard, the latter could be considered as undermanned. This is due mainly to the manpower shortage of the present era. Thus, while the payroll is nearly equal at both plants, the total yearly flow at Boulevard is 50 per cent greater than at East Street and accounts in a large measure for the smaller cost per million gallons of sewage treated. Consequently, in the design of plants, other factors should be investigated.

Flow diagrams of the New Haven plants have been prepared for convenience of plant employees. Instead of lines and notations, mechanical equipment is shown in its approximate outline and location. This makes each operation more understandable to the operator and should envision equipment and its function more clearly to the uninitiated.

By use of colors, the various removals or changes can be more readily brought out. For instance, if the influent is colored blue with brown dashes scattered throughout, then in the sedimentation tanks, by showing a solid brown color at the lower level and tinting the upper level in blue, the settling out of the solids can be clearly demonstrated.

Fig. 5 illustrates other charts used to advantage in picturing operation data gathered in the New Haven sewage treatment plants. Other charts showing fixed and volatile solids and gas production and consumption are useful and valuable. Each one condenses a long story into limited space.

In general, remembering the key word "accuracy," charts will show the over-all operating accomplishment. A close study by the operator can result in the reasonable attainment of that ever elusive Utopia of plant operation—maximum efficiency.

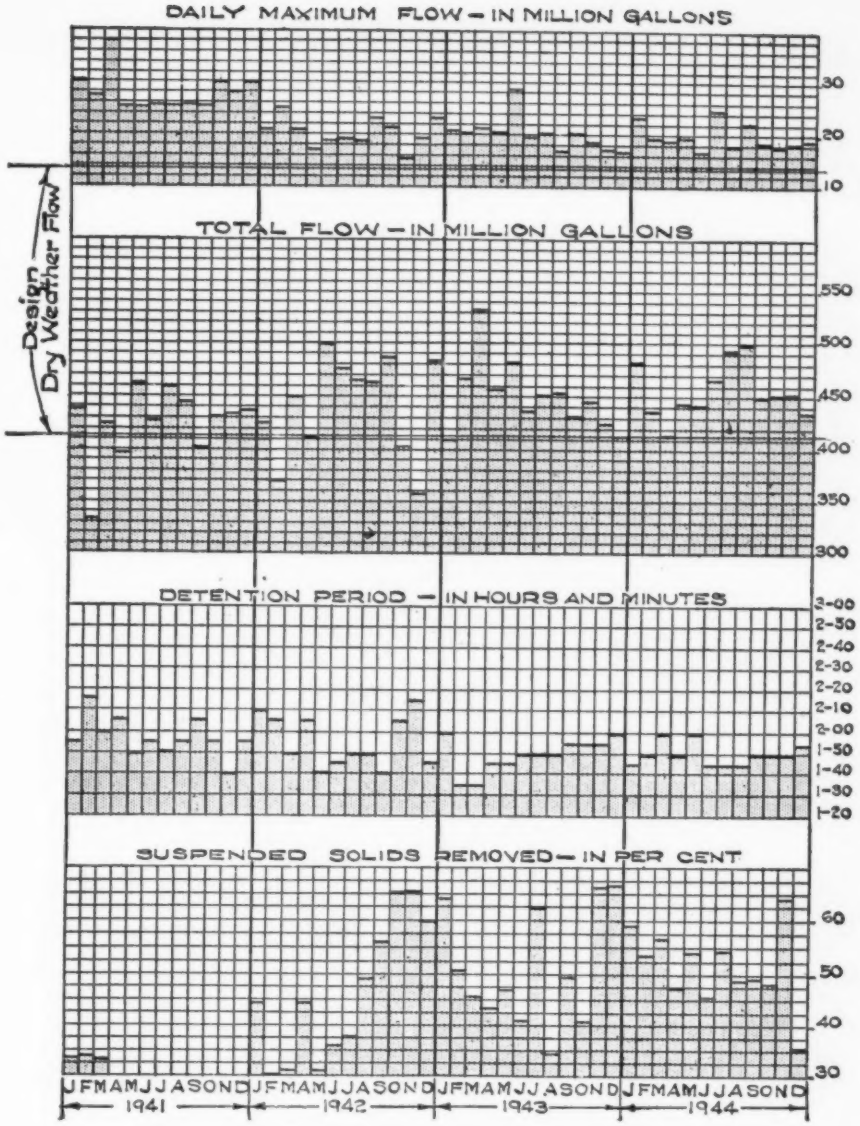


Fig. 3.—Sewage Flow and Sedimentation Chart, Boulevard Plant, New Haven, Conn.

Plant	Year	Type	Flow M.G.	Screenings Cu. Ft.	Grit Cu. Ft.	Raw Sludge Gals.	Sludge to Filters Gals.	Sludge Cake Incinerator Lbs.	Sludge Cake to Trucks Lbs.	Gas Thousand Cu. Ft.	Hours Incinerator Operated	Power Thousand K.W.H.	Fe Cl3 Lbs.	Cao Lbs.	Ash Lbs.	Oil Gals.	Total Cost	Cost Per M.G.
EAST ST.	1941	SI	3130	7659	12090	1876127	3192701	4764421			2260	135	8795	123527		1193	36051	11.52
EAST ST.	1942	SI	3527	7997	11040	2569546	2369875	3765286			2084	134	10,293	115274		1326	42214	11.97
EAST ST.	1943	SI	3411	21870	13783	2343019	1586000	2050541			1144	112	8975	78194		821	43454	12.73
EAST ST.	1944	SI	3653	14862	12404	2233112	1771677	2781861			1534	123	8955	64993		1394	45198	1240
BOULEVARD	1941	SDI	5085	3933	15971	6444678	2903615	3514728		19154	1499	854	32392	170739		3164	44205	8.72
BOULEVARD	1942	SDI	5295	3166	13430	6610914	3322089	3895258		19315	1421	872	31923	129641		6916	49044	9.28
BOULEVARD	1943	SDI	5413	3737	13143	5693200	2817004	3350420	287000	16532	1490	858	30581	123382		9268	48479	8.93
BOULEVARD	1944	SDI	5475	3614	17358	5420800	5021139	6703691	455000	18496	2706	894	41280	198239		4196	53278	9.75

S = Plain Sedimentation. D = Digestion. I = Incineration.

Fig. 4.—Annual Operation Statistics at New Haven Sewage Treatment Plants.

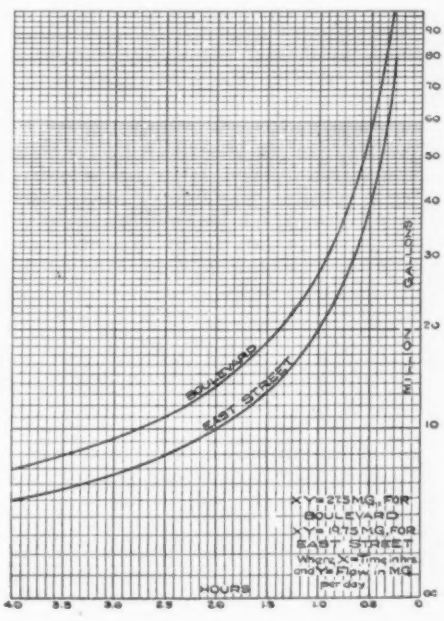

BOULEVARD
EAST STREET
XY = 2.13 MG. FOR BOULEVARD
XY = 1.475 MG. FOR EAST STREET
Where X = Time in hrs and Y = Flow in MG per day
HOURS
MILLION GALLONS

Fig. 5.—Primary Sedimentation Tank Detention Period Chart.

* * *

WATER WASTE DETECTION BY OBSERVING SEWER FLOWS

By D. D. GROSS, Chief Engineer
Board of Water Commissioners
Denver, Colorado

COLORADO'S pioneers came looking for gold, but stayed to learn that when the welfare of man is considered, water is more valuable even than the glittering nuggets which spelled wealth to the fortunate.

The gold-rush with the famous slogan "Pike's Peak or Bust," resulting in the founding of Denver and the settlement of Colorado, started in 1858. As Colorado grew the demand for water grew and as the demand for water grew the laws governing the use of water grew. The water laws provide that "the first in use is the first in right" to water flowing in Colorado streams. As the requirements of water for irrigation developed faster than the requirement of water for municipal purposes, Denver found it necessary to buy rights to *the use of water,* which implied its return to the streams.

The Importance of Returned Water—Sewage

There seemed to be a policy on the part of irrigation interests to institute litigation to prevent Denver from obtaining more of the direct river flow. It became very important therefore that Denver have available complete and accurate information as to the per cent of water that was returned to the river through the sewers, as well as a record of that taken into the water supply system.

In Colorado we do not consider it good form to talk about the *consumption* of water; it is better to say the *use* of water, fostering the thought that after use much of it is returned to the river. So, we must consider two kinds of water—"new" and "used."

To get at the facts as to the per cent of water used in Denver that was returned to the river we began in 1926 the keeping of records showing the flow of water through the sewers. Charts are prepared on which are shown the use of water in the city. That is the flow of water as metered in the supply conduits, and this flow corrected for loss or gain in the city distribution reservoirs. On the same charts are plotted the amount of flows in the sanitary sewers. This information is computed and plotted for two-hour periods throughout the 24 hours of the day and continually throughout the year.

What Was Learned from the Records

By a study of the charts, such as that here reproduced, over a long period of time we learned that when water was not being used for lawn sprinkling or similar use not capable of return through the sewers, that 95% of the water used was being returned through the sewers. We take this as evidence that there was very little loss of water through leakage in the city pipe system as the ratio of "used" water to "new" water remained fairly constant as the use of water increased or decreased.

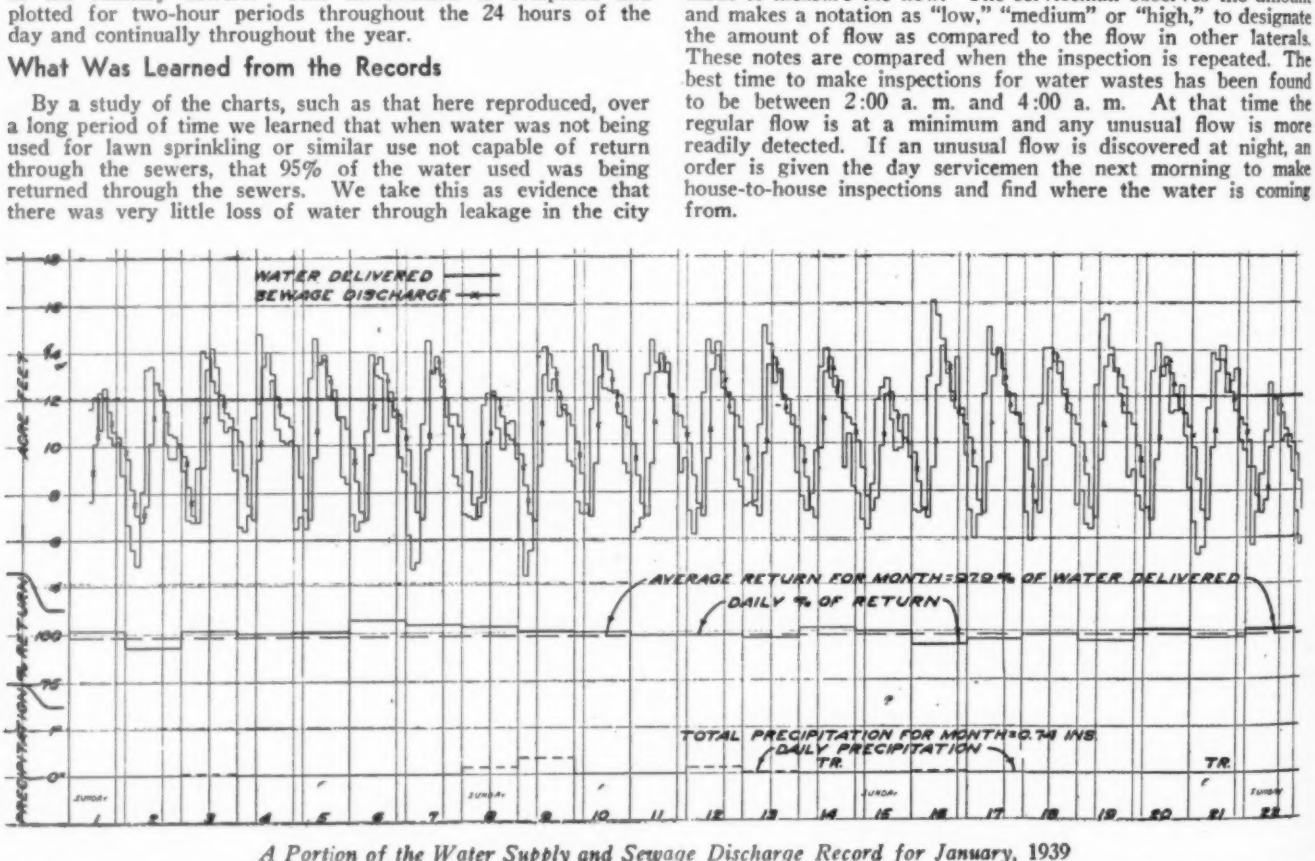
Our experience over a period of years convinces us that both the sewers and water mains are tight, with very little infiltration (say 10%) of ground water into the sewers and very little leakage from the city water mains. When leaks develop in the mains or services the water usually comes to the surface and is detected. However such is frequently not the case and leaks enter somewhere.

A few years ago when we had a cycle of dry years, necessitating a publicity campaign asking the people to conserve water and avoid waste, there was a noticeable reduction in the flow in the sewers. The same condition is observed when an extensive campaign of house-to-house inspection of plumbing is made.

Possibilities of the Scheme and a Plan

At the suggestion of Mr. L. H. Enslow, Editor of WATER WORKS AND SEWERAGE, we decided to make still further use of our sewer gaugings to determine or detect the improper use of water (water theft) in addition to tracing possible hidden leakage of moment.

Under this plan men are sent to inspect sewer manholes for unusual flow of water. We have constantly on duty men we term "servicemen." They are provided with pick-up trucks equipped with radio, maps and tools. It is their duty to respond to all important fires, operate valves, locate leaks, post red lights, etc. At headquarters we have a foreman and two or more men always on duty. If all the men are away from headquarters it is possible for the foreman to get in touch with any one of them at any time as the police department broadcasts our messages. When not otherwise engaged the servicemen do this work. They inspect the manholes at the points where the smallest laterals discharge into the branch sewers. Most of these laterals are from one to three blocks long. No attempt is made to measure the flow. The serviceman observes the amount and makes a notation as "low," "medium" or "high," to designate the amount of flow as compared to the flow in other laterals. These notes are compared when the inspection is repeated. The best time to make inspections for water wastes has been found to be between 2:00 a. m. and 4:00 a. m. At that time the regular flow is at a minimum and any unusual flow is more readily detected. If an unusual flow is discovered at night, an order is given the day servicemen the next morning to make house-to-house inspections and find where the water is coming from.



A Portion of the Water Supply and Sewage Discharge Record for January, 1939

(Note that sewage flows lag behind water use rates by roughly two hours. Note also that sewage flow for month averages almost 98% of water supplied distribution system in a month of negligible infiltration expectancy.)

EVALUATION OF SEWAGE WORKS DATA

By GEORGE E. SYMONS, Ph. D.
Associate Editor, Water & Sewage Works, New York, N. Y.

"GETTING the Most Out of Sewage Works Data," by William L. Havens and Frank Woodbury Jones,[1] presented some very pertinent considerations. As partners in the consulting engineering firm of Havens & Emerson in Cleveland they are well aware that "frequently a study of reports from a sewage treatment plant reveals omissions and discrepancies which make it difficult to draw useful conclusions."

These authors state that "sewage works data should be obtained, recorded, preserved and examined frequently for three chief purposes: (1) To serve as evidence of past performances; (2) to show current accomplishments as regards adequacy, economy and effectiveness of treatment processes, and (3) to determine the need for extensions and improvements and to provide a sound basis for design of such betterments."

In their paper Messrs. Havens and Jones made "an appeal to greater care in the accumulation of data, to the end that the information may be utilized more effectively . . ." With their intent, their appeal and their conclusions this writer has no quarrel. Neither is it a criticism to point out that they have presented their appraisal of data and its evaluation principally from the point of view of the designing engineer rather than the analyst. This attitude is understandable and appropriate, but it leaves the matter open for discussion from the point of view of the plant operator and laboratory analyst. This discussion will therefore be concerned with a comparison of this point of view with that taken by the authors of the paper.

In the above listed chief reasons for the collection, preservation and examination of sewage works data, the authors do not omit the concept of improving operation, but it would seem worth further emphasis. From the operator's point of view, data when properly compiled and interpreted may be most useful in betterment of the plant operation long before there is any improvement in design or reconstruction. In short, proper use of routine data may allow for research into the matter of improving operations of the plant with which one has to work.

In the matter of chemical analyses to be made, Havens and Jones have omitted one important determination in the list of analyses "appropriate to the problem at hand"—namely chlorine demand; likewise, the determination of settleable solids should not be overlooked.

Laboratory Work

There is no doubt that "for complete and effective evaluation" of results, analyses should be made of samples collected at all points indicative of major treatment and the number of tests made should be sufficient to obtain information on what happens to various constituents of sewage.

In simple words it must be pointed out that "that's a lot of work," and a realization of the amount of that work must be kept in mind when considering the following comments of the authors: "Another important link in the chain of information is the laboratory. This link may be weakened by carelessness or sloppy and inept procedures. Witness the laboratory assistant who constantly misread his balance weights and, which is quite common, made mistakes in simple calculations. A laboratory, even one fully equipped with all necessary apparatus, becomes of little account if the work is done without due regard to the necessity for careful and correct technique."

There is but one answer to these comments. Engineers cannot blithely say, on one hand, that the janitor, the office boy or an operator can be easily taught to do sewage analyses, and, on the other hand, ask for careful work, free of sloppiness. Larger plants should have trained chemists, and smaller plants should have operators taught in short schools and certified for their positions.

Sampling

There is no doubt that in the chain of information the sample is the first important link. Whether automatic samplers will obviate the weakness of this link cannot yet be fully answered, and, as the authors point out, human samplers are not always reliable. From this writer's experience, too, numerous instances may be cited wherein the human element was the weakest link in the sampling. Weakness ran all the way from the downright dishonesty of a sampler to misplaced good intentions. The former was exemplified by the man who, on a night shift during an industrial waste survey, took over at midnight and slept in the truck until 7 a.m., then filled all eight sampling bottles and recorded faked flow data. It was his lack of knowledge of sewage flow that tripped him, for his guesses on flow data were quite wrong and the samples didn't "look right" to the chemist.

In the case of the good intent gone wrong, one may cite the sampler who had heard the chemist discussing B.O.D. and aeration. He noticed that when he took a sample of flow from a V-notched weir discharge, the sample was aerated in the bottle, so he plunged the sample bottle beneath the surface behind the weir; in so doing he plunged the bottle too deep and half filled it with garbage particles that had settled behind the weir over a period of two weeks. The sample was hardly representative.

Domestic and Storm Loads

On many occasions engineers have set up a series of evaluations of data from which it appears possible to ascertain domestic, industrial and storm loads separately by the proper tabulation of the data. Such formulas are correct only if certain assumptions are made. These assumptions are that on Sunday all industrial activity stops, and all domestic, i.e., human activity, is the same as during the week, but not all industrial activity ceases on Sunday and it may also be doubted that the household activity is normal. Persons who rise late, eat only two meals, are less active, drink less water, wash less often, use the toilet less often, certainly are not discharging the normal amount of sewage per capita. Perhaps this is not an important factor, and yet it should not be entirely overlooked. The assumption of Sunday as a normal domestic day may lead one to assume that any season is as normal as another.

Such an assumption in one instance led to a question as to the accuracy of data on one large sewer serving a population of over 100,000 because the population equivalent, both as to B.O.D. and suspended solids, was 10,000 less in the summer than in the winter. Careful consideration of all factors showed that the exodus of college students from the area plus the exodus of persons to summer homes could readily account for the difference.

Analysis of Composite Samples

Quite often tabulated data will show that analyses of a composite sample give comparable results to analyses of the individual samples, but there are certain warnings that must be expressed in this connection. Data for individual samples of 24-hour composites are less likely to agree than composites and individual samples over shorter periods of five to eight hours.

This writer has shown that composite samples are of no value for bacteriological results or for the determination of chlorine demand. Dr. W. D. Hatfield at Decatur, Ill., has shown that unless composite samples are kept at temperatures below 4° C., there will be a decrease in B.O.D. Dr. Anthony Fischer of the Dorr Co. has shown that flocculation of colloids occurs during long standing. Such flocculation obviously affects the suspended solids test. There seems to be no better way at present, however, than to accept as approximately true the analysis of composite samples, because individual grab samples are meaningless as to operation of a sewage treatment plant.

Solids Balance, Sampling, Analytical Technic

In the matter of solids balance, as Messrs. Havens and Jones point out, data on suspended solids, total solids and actual sludge measurements frequently show wide discrepancies, thereby leading to the belief that the analytical data are untrustworthy. While not insisting that all analytical data are correct, at the same time it may be pointed out that several factors contribute to this discrepancy in data. The first of these is location of sampling point.

Where samples are collected by hand, by the immersion of a sample bottle or sampler, it must be remembered that sewage flowing through a conduit does not necessarily have the same composition from top to bottom, and this difference is more noticeable where analyses for grit removal are made. Because of the difficulty of obtaining samples that had the proper proportion of grit therein, the practice at Buffalo, N. Y., has been to analyze the grit-free sewage, analyze the grit (which was weighed), and calculate the suspended solids content of the raw sewage.

Another factor to be considered is that of laboratory technic where the test portions are removed from the sample bottle for analysis. It has always been customary practice to shake the bottle of sewage or sludge and then pour or pipette out the sample, or insert a volumetric flask into the neck of the sample bottle and invert to fill the measuring flask. Any of these technics will introduce errors into the test by reason that none overcomes the tendency of suspended solid particles to settle during sampling.

To obviate this difficulty, Dr. W. D. Hatfield has introduced the technic of

mixing the sample with an electric stirrer in the sampling container and withdrawing the test portion by siphon, while the sewage sample is in motion and settling prevented. This technic has the advantage that all samples withdrawn are of the same composition as to suspended matter contained.

There is one other factor that may affect the results in a suspended solids test. The use of the Gooch crucible has its limitations. Results of studies have indicated that the suspended solids results depend on the thickness and porosity of the Gooch mat. Studies made by Smith in Chicago developed the use of an aluminum dish and filter paper for suspended solids in activated sludge. This technic was adapted for use in the determination of suspended solids in raw and settled sewage at Buffalo. The results were uniformly good, for one reason because larger samples were used for the test than are usually used, and for another because the sampling error was correspondingly reduced. While this technic has been accepted for activated sludge solids, in the 9th Ed. of Standard Methods it certainly should receive further study for its application to raw sewage.

Messrs. Havens and Jones also point out that sampling of sludge by the operators is not always satisfactory. This is likewise true in the laboratory. Shaking of a sample bottle of sludge followed by pouring will not give a true sample of the sludge in the bottle. The neck of the bottle acts as a dam holding up the heavier particles. Shaking followed by thiefing with a glass thief sampler produces analytical results that are more nearly correct than does any other method of sampling.

Costs

The writer is in agreement with the idea of reporting costs on per capita basis. Actually, where strong industrial wastes are included in the sewage, it would seem that to report the cost of operation on a population equivalent basis would serve better for comparison of one sewage treatment plant with another. But it should be remembered that it is not strictly possible to compare two treatment plants that do not have the same type of treatment or the same problems of waste concentration.

Weighted Data

There is one other consideration to be given to the evaluation of sewage works data. It has generally been quite common to determine the analytical results in ppm. and then ascertain the mathematical average of these concentrations as a measure of plant operation. Straight mathematical averages are often incorrect. Weighted averages are the only true averages. These averages must be weighted according to the flow represented by the analyses. The use of quantity units (lb. per day, for example) is a more desirable practice. A full realization of this fact becomes evident from the following simple example:

	Flow mgd.		ppm.	Quantity Unit
1st day	2	×	300	600
2nd day	3	×	200	600
2 day avg.	2.5	×	250	...
Wtd. avg.	2.5		240	600

Obviously the average flow is 2.5, but whereas the mathematical average of the ppm. is 250, the true weighted average is 240 ppm. Another means of reporting the average results for a month, for example, is to use the median values of the series of observations. The median is much nearer to the weighted average than is the mathematical average in most cases. The latter approaches the median and the weighted value only when the two variables (flow and concentration) are relatively constant.

Reports

Too often the data from properly collected and properly analyzed sewage samples are buried in improperly designed record sheets. In other instances, laboratory and operating data that have direct relationships to each other are not recorded in a manner to indicate those relationships. In either case poor operation may result because the information needed is not properly at hand.

Whereas it may be desirable to collect data on many analyses and on many phases of operation for research purposes, perhaps not all of the analyses have a direct bearing on plant operation and such data therefore should not clutter up the operating report. For example, in a treatment plant using only primary treatment, the determination of nitrogen may be desirable for long range research studies, but it has little if any bearing on the operation, whereas suspended solids and flow are vitally important.

In the averaging of tabulated data, it is mathematically incorrect to obtain an average per cent removal (a per cent reduction or per cent kill of bacteria) by averaging the daily per cent removals. The true average per cent removal may be obtained only by determining the weighted average values of, for example, influent and effluent analyses, and then calculating the per cent removal.

The complexity of reports will vary with the size of plant and type of treatment. Suggested forms for small plants have appeared in the Reference and Data section of this magazine in April, 1946, and a system of multiple page records for a large plant was published by this writer in *Sew. Works Jour.* in 1941.

One may well agree with the conclusion expressed by Messrs. Haven and Jones that "there is no point in amassing voluminous data unless those data present a true story of what has happened, what is now taking place, and what is likely to occur in the future."

Reference

[1]Havens and Jones, *Civil Engr.*, p. 399, Sept., 1945.

EQUIPPING THE SEWAGE PLANT LABORATORY

With Particular Reference to the Smaller Plants

By NORMAN C. WITTWER, Consulting Engineer
Trenton, New Jersey

SEVERAL excellent articles have been published on the arrangement and functions of large sewage treatment plant laboratories, but very little definite information is available pertaining to a laboratory suitable for sewage plants of from 0.5 m.g.d. to 10.0 m.g.d. capacity. It is the purpose of this article to describe in detail the furnishing, equipping and arranging of a compact laboratory suitable for necessary routine control and statistical determinations.

No discussion will be made of the methods of sewage analysis, or of laboratory technique, as these subjects are thoroughly covered in such publications as the "Standard Methods of Water Analysis," published by the American Public Health Association, and "Analysis of Water and Sewage," by Theroux, Eldridge, and Mallman, published by the McGraw Hill Book Co., New York City.

The laboratory herein considered is complete in every respect for the average sewage treatment plant, although special conditions or plant processes may require some additional facilities. The analyses which may be performed in the laboratory to be described are:

Solids—Suspended, Dissolved and Volatile.
Sludge—Moisture, Solids, Ash.
Sludge Index (Activated Sludge).
pH—Sewage and Sludge.
Dissolved Oxygen (D.O.).
Bio-chemical Oxygen Demand (B.O.D.).
Oxygen Consumed.
Chlorine Demand.
Residual Chlorine.
Relative Stability (although not recommended).

Special apparatus has not been provided for sewage gas analysis, nitrogen determinations, or for bacteriological work. Such determinations are not ordinarily a part of routine laboratory work, although many of the larger plants undertake more extensive analyses.

Laboratory Furniture

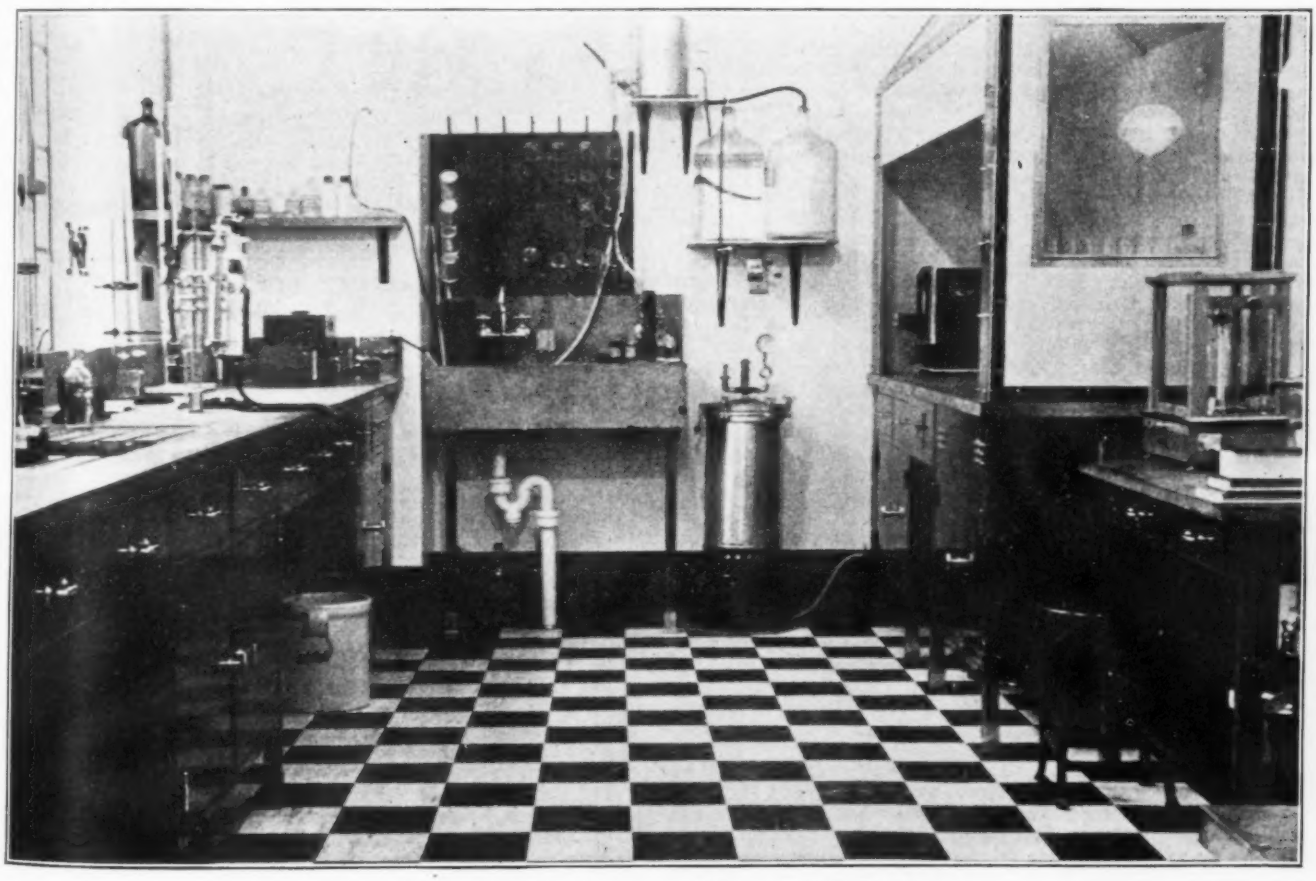
The scope and arrangement of the laboratory is of prime importance. Many plant laboratories have been laid out and constructed with but scanty appreciation of the facilities required. Since cost is in most cases of great importance, it is the aim of the author to present a laboratory which is compact, entirely complete for the purpose intended, and yet as economical as is possible without sacrificing needed facilities or necessary quality of equipment and apparatus.

Such a laboratory is complete in a room 12 feet wide by 15 feet long. It is based on the experience gained in the author's own laboratory, and in laying out laboratories for other plants.

Certain fundamentals are essential, and must be provided if the worker is to be expected to properly perform his duties. They are as follows:

1. Adequate work table space.
2. A suitable sink with goose-neck faucet with at least 15 inches clearance above sink bottom, and a peg board for draining and drying glassware.
3. A dependable supply of distilled water.
4. An adequate number of gas, air, hot water and cold water hose cocks, and other necessary connections.
5. Fume hood with forced ventilation.
6. Balance table.
7. Electric refrigerator for storing and preserving samples.
8. B.O.D. Incubator.
9. Drying oven.

*When this article was written the author was Supervising Engineer for the Rahway Valley Joint Meeting, the authority which operates the sewer systems and a central treatment works for Rahway, N. J., and eight other participating municipalities.—Ed.



One End of the Laboratory—Rahway Valley Plant

10. Steam bath.
11. Muffle furnace (for ashing solids).
12. Arrangement for filtration through Gooch crucibles.
13. Cabinets for reagents and solutions.
14. Shelving for small bottles, etc.
15. Cupboard and storage space for glassware, miscellaneous equipment and supplies.
16. Adequate light, a very important consideration.

Furniture Specifications

Laboratory workers differ in their preferences for wood or steel furniture, and for stone or hard-wood work-table tops. This is not so important, as both have proven satisfactory. A set of detailed specifications are given below, which are extracted from the contract specifications for a sewage treatment plant laboratory now under construction. These specifications are for steel equipment, but can be readily adapted to wood furniture if so desired.

1. *Make of Furniture*—The furniture installed under this contract shall be from a manufacturer who has made at least five satisfactory installations of steel laboratory furniture of materials such as are herein specified, and which installations have been in satisfactory service for two or more years.

2. *Steel*—Sheet steel shall be of a copper-bearing steel alloy, containing not less than one-quarter of one per cent copper, and shall be hot-lead-coated on both sides, on sheared edges and spot welds so that the steel shall be fully protected against corrosion. All sheets shall be prime grade, stretcher-levelled, free from uncoated spots, deep scratches or other injurious defects. All drawer heads and cupboard doors shall be of No. 12 gauge thickness; drawers and small shelves shall be of No. 20 gauge, all other sheet steel work shall be of No. 18 gauge. Gauges specified above and elsewhere herein are U. S. gauge.

3. *Cabinets and Supports*—All cabinet work shall be sanitary, vermin-proof flush type, without recessed or projecting panels. It shall be designed and constructed for laboratory use, with pipe ducts, racks, removable backs, shelves and adjustable legs for levelling.

Sides, backs and bottoms of cabinets shall be of No. 18 gauge. Sides of cabinets shall be of one piece, formed into a U-shaped corner post at the front, the inner sides of which shall be formed into a door strike. The upper and lower edges of the cabinet sides and back and front rail shall be formed into a channel member ,reinforced with a continuous angle frame of 1¼ x 1¼ x ⅛ inch copper steel, mitred and welded at the corner, to which the legs shall be welded. Backs and shelves shall be removable from the inside, so that piping may be installed or removed without dismantling any part of the table. Backs shall fit into clips at the bottom. At the top, the back shall be flanged in a 7/16 inch flange or back panel, and shall be held in place with two screws at the ends.

Legs of cabinets shall be of No. 14 gauge, 1½ inch square seamless tubing, 8 inches high; and shall be acetylene-welded to the angle iron frame of each individual cabinet at the bottom of the cabinet. After the legs are welded to the frame, the frames with th eattached legs shall be dipped into a vat of hot lead so that all surfaces and welds shall be fully coated and protected. Each leg shall be fitted with a drive fitting, non-ferrous die-cast, micro-levelling device, with six prongs and clip wells. The shoulder of the levelling devices shall rest on the bottom of the square tube legs, and shall then be permanently attached to the leg by forcing the metal leg into the depression on the device. The shoulder shall extend ¼ inch below the bottom of the leg. Each levelling device shall be fitted with a 2½-inch long hexagonal bolt, cadmium plated and furnished with stainless steel floor plates. The levelling device shall be covered with a duraluminum shoe cover plate as hereinbefore specified.

Cupboard doors shall be of No. 12 gauge, hung on a pair of No. 10 gauge, lead dipped, offset, five knuckle hinges, with round head brass fixed pins and with concealed flaps; one flap shall be blank and welded to the door, the other shall be fastened to the cabinet post with three bolts. Doors shall be provided with a lead-plated three-way locking device, locking both doors at the top, bottom and center at one time by a not less than 2⅜ x 1⅜ inch oval shaped, solid cast aluminum alloy knob with a ⅜ inch square brass stem cast and pinned into the knob engaging a stamped locking cam of No. 12 gauge and two ⅝ x ⅛ inch sliding bolts.

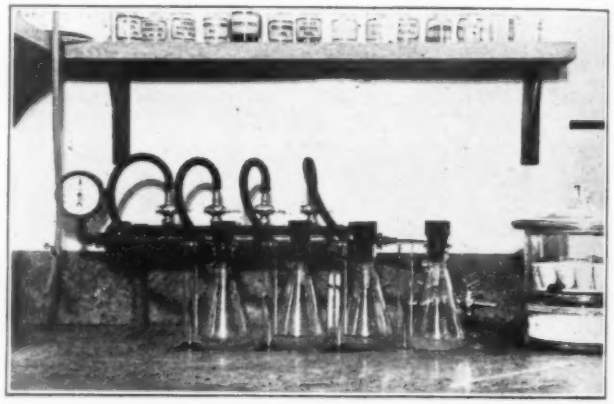
Drawers shall be of No. 20 gauge, the upper edge of the sides and back of which shall be reinforced and formed into a U-shaped head. The front of the drawers shall be of No. 12 gauge. Each drawer shall operate on four ⅞-inch diameter cadmium-plated ball-bearing rollers, operating on extension channel runners. Runners shall be formed of No 14 gauge, and shall support the drawers rigidly when extended the full length. The drawer stop shall be fastened to the bottom of the drawer, and shall be concealed at all times. Drawer pulls shall be graceful in design and shall be of cast-aluminum alloy, fastened from the inside of the drawers with concealed aluminum alloy screws. The drawer pull shall not extend into drawer.

4. *Hardware*—All hardware, including the kick-plate shoes, shall be as described under laboratory cabinet construction and shall be of cast silicon-aluminum alloy, ground and polished to a satin finish. All screws shall also be of same aluminum alloy. All cocks and table fixtures shall be chromium plated.

5. *Finish*—All surfaces of steel work of laboratory equipment shall be first washed clean with benzine to remove all the oil and grit. Then one coat of neutral metallic filler shall be applied, baked and sanded; then one coat of rust preventing primer baked and sanded; finally two coats of dark green acid and alkali resisting enamel shall be applied.

6. *Main Work Table*—The main work table along the front wall of the laboratory (see plan) shall be 15 feet long (approximately) by 2 feet 6 inches wide by 37 inches high. The table top, the 6-inch high back, and the 4-inch cut-out at the window shall be of 1¼-inch soapstone. The sink in the table shall be 18 x 16 x 8 inches deep, and furnished with a Duriron waste fitting. The table shall be supported on complete combination drawer and cupboard units, with a 5-foot clear opening in front of the window. Drawers shall be provided for the full length of the table, with a dummy drawer in front of the sink to match the rest of the equipment. A 12-inch deep open shelf shall be provided across the clear opening in front of the window, with flange-up back and flange-down front. It shall be mounted at the bottom of the cupboard and toward the rear of the opening.

7. *Vacuum Manifold*—The table shall be equipped with one vacuum manifold fitted with four 3-way exhaust cocks and one 3-inch dial vacuum gauge. The manifold shall be mounted on suitable supports at the back of the table, and connected to the vacuum pump cock by means of flexible copper tubing with compression type couplings.



Vacuum Manifold and Filter Flasks
(Used in determination of total suspended and settleable solids. On right Gooch crucibles in desiccator.)

The 3-way cocks shall be fitted in the side of the manifold facing the front of the work table.

8. *Fittings for Main Work Table*—The sink shall be fitted with one combination hot and cold water goose neck drop faucet with hose end, the goose neck to be of such height as to clear 1000 ml. graduated cylinders. A cold water faucet shall also be provided, same to have a screw-type opening suitable for a Chapman aspirator. The table shall also be equipped with one pedestal type single air pressure cock, three pedestal type double gas cocks, and one pedestal type cold water cock.

9. *Vacuum Pump*—There shall be installed on the shelf of the cabinet space under the sink a suitable blower and vacuum pump for the operation of the vacuum manifold. These conditions are satisfied by a Cenco Rotary air cooled blower and vacuum pump driven by a ¼ horsepower motor mounted on a common base. (The electrical current characteristics must be given for the motor.) The motor shall be controlled by a push-button switch located at a convenient point on the wall above the main work table.

The vacuum side of the pump shall be connected with ¼-inch copper tubing, or extra heavy vacuum rubber tubing, to the exhaust manifold as indicated on the drawings. The pressure or exhaust side of the pump shall be connected to the air cock on the main work table with ¼-inch copper tubing.

10. *Work Table Shelving*—There shall be furnished and in-

stalled on the wall above the main work table, 1¼-inch thick by 6 inches wide soapstone reagent shelving mounted 22 inches above the top of the work table. The shelves shall extend along all walls of the work table, except for the window and peg board. The shelves shall be supported on suitable brackets, securely fastened and anchored to the building wall.

11. *Peg Board*—There shall be mounted on the wall at the right end of the work table a peg board of carbonized wood, 24 inches wide by 30 inches high.

12. *Fume Hood*—The fume hood shall be an open type fume hood 5 feet long by 2 feet 6 inches wide. The work table of the hood shall be supported by one 2½-foot combination drawer and cupboard unit. The hood shall be furnished with one 1000-watt pedestal-type duplex electric receptacle, two pedestal-type double gas cocks, one pedestal-type double water cock, and one four-hole gas-heated steam bath.

The steam bath shall be fully insulated, with a gas vent opening on the inside of the fume hood. The steam bath shall be constructed of No. 18 gauge stainless steel, and equipped with stainless steel concentric rings to cover the four 3¾-inch diameter openings. The bath shall be of the quick-steaming type, equipped with a suitable external water level regulator. A Hoke-Phoenix needle valve shall be used to control the water supply to bath, and the bath overflow shall be visible.

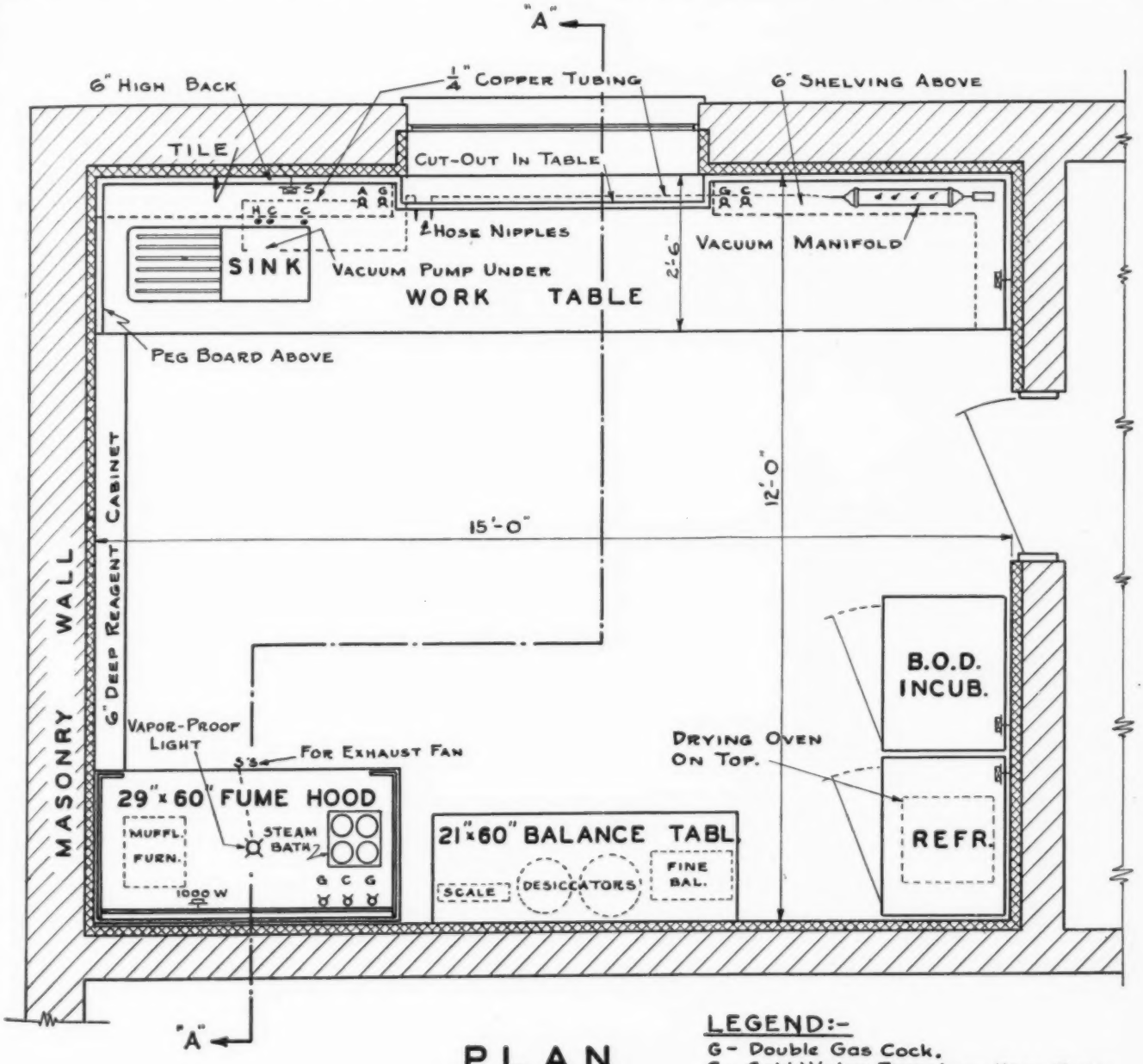
A suitable opening and connection shall be provided through to the top or rear of the hood for the installation of the exhaust fan.

13. *Hood Exhaust Fan*—A suitable exhaust fan shall be installed to exhaust the fume hood. The fan shall have a capacity to discharge not less than 225 cubic feet of free air per minute at free delivery.

The fan suction and discharge piping shall be of suitable acid fume resisting material, such as "Labite," "Transite," or vitrified tile. All joints shall be air tight, and the joints at the fan shall be made with high-grade, heavy rubber tubing to prevent vibration.

The exhaust piping shall terminate at the roof in a suitable size ceramic ventilating roof cap, properly flashed to the roof.

14. *Other Shelving*—There shall be furnished and installed the necessary shelving for the water still and the two 5-gallon distilled water carboys. If possible, the water still can be mounted on top of the reagent cabinet. The shelf for the 5-gallon car-



PLAN

LEGEND:-
G - Double Gas Cock.
C - Cold Water Faucet or Hose Cock.
H - Hot Water Faucet.
A - Air Cock.
S - Switch.
- Duplex Electric Outlet.

Suggested Layout of Sewage Works Laboratory

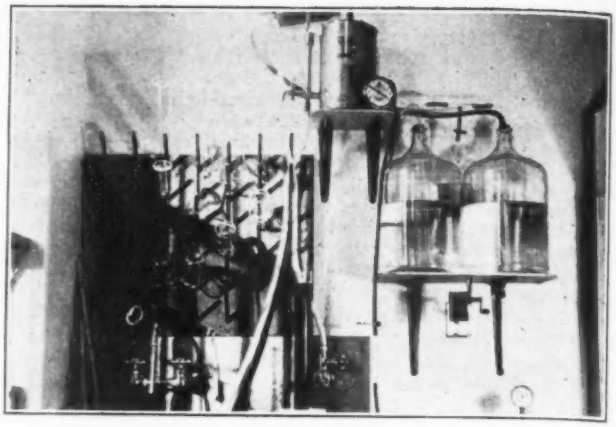
boys shall be of ¾-inch Labite or Transite, 22 inches wide by 11 inches deep. It shall be mounted on heavy brackets of sufficient strength to carry the weight of the bottles, when full.

All brackets shall be securely fastened and anchored to the building wall.

15. *Balance Table*—The balance table shall be 5 feet long by 1 foot 9 inches wide by 2 feet 7 inches high, and shall be constructed of 1⅝-inch diameter tubular steel with a cross bar at rear only to provide ample leg room. The floor flanges shall be such as to permit levelling of the table. A 4-inch high panel shall be provided under the table top into which shall be fitted two small drawers. The table top shall be of 1¼-inch selected soapstone.

16. *Reagent Cabinet*—There shall be furnished and erected an enameled steel reagent cabinet, 7 feet high and of suitable length, and 6 inches clear depth. The cabinet shall be constructed of No. 18 gauge steel with sliding steel doors glazed with No. 1 clear glass. The cabinet shall have five shelves, adjustable in height. The cabinet shall have three front legs, with provisions for bolting the cabinet securely to the wall.

The approximate cost of the laboratory furniture specified above is $1,250.00.

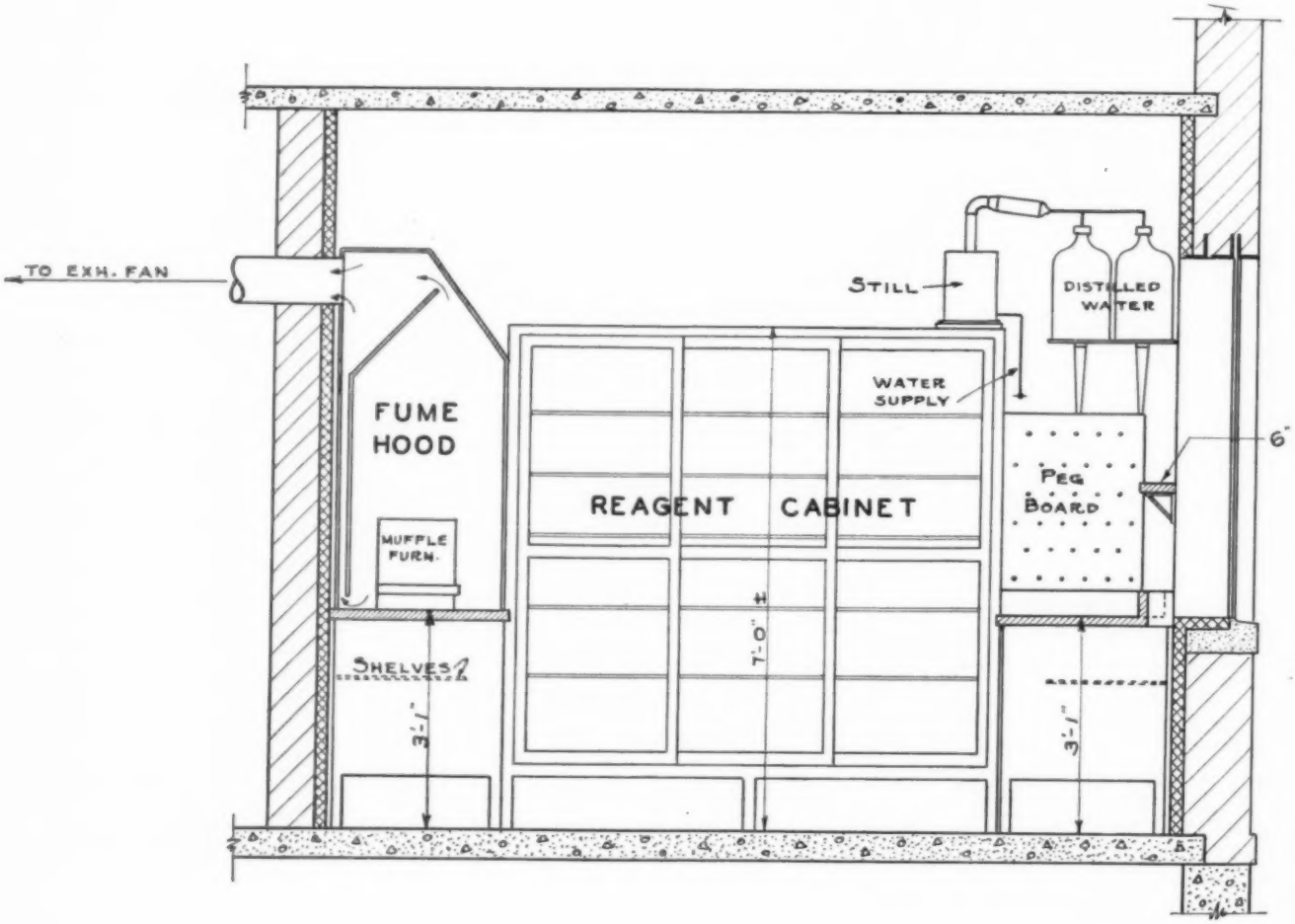


Peg-board Above Sink and Water Still on Right

Permanent Apparatus and Equipment

In addition to the laboratory furniture, certain permanent apparatus will be required. The following list of this apparatus, as well as the "Minor Equipment Items" list and the "Reagents and Chemicals" list, has been carefully compiled, and checked against the equipment and experience of active plant laboratories. The "loading up" of the laboratory with unnecessary or little-used apparatus and equipment has been avoided. Enough equipment has been included to enable the chemist or operator to walk into the laboratory and commence work, without the all-too-customary wait for necessary items not originally included.

In the preparation of such lists, cognizance is taken of the fact that certain manufactured items of equipment and apparatus have been found to be the most satisfactory for use in a sewage plant laboratory. It is also recognized that a general description of a particular item without the corresponding manufacturer's name or catalog number will not always enable a purchaser to obtain the article intended. Therefore, wherever deemed advisable, the manufacturer's name or dealer's catalogue number is



SECTION "A-A"

Suggested Layout of Laboratory—Section "A-A"

included in order to eliminate errors in the purchase of this equipment. Wherever possible, more than one manufacturer or dealer will be given.

The following abbreviations will be used throughout for several of the more prominent supply houses:

Arthur H. Thomas Company.....AHT
Eimer & Amend.....E&A
Central Scientific Co.....CSC

The catalog numbers thus given can be considered as standards of quality by which other competing houses can offer their merchandise.

Quantity	Description
1	B.O.D. Incubator 5 to 6 cu. ft. capacity (give current characteristics).
1	Analytical Balance with chain balance with channel notched beam, sensitivity to 1/20 mg. with magnetic damper, Christian Becker chainomatic No. 16, or E&A 16772/2.
1 set	Analytical Balance weight, 1 gm. to 100 gm. for chain balance.
1	Rubberized Balance Cover to fit balance.
1	Triple Beam Balance with agate bearings, including sliding weights and 500 gm. and 1000 gm. attachments. Equal to E&A 17026, 17026 A&B, or CSC 3600 & 3610.
1	Beckman pH Meter (Industrial Model).
1	Taylor-Enslow Slide Chlorimeter (where chlorine is being used).
1	Muffle Furnace, MU Type 62 Electric and Encased Rheostat (give current characteristics).
1	Electric Drying Oven, inside dimensions approximately 12" x 12" x 15", with inside glass door. Elconap Type BO 15, or Weber Type B (give current characteristics).
1	½ gallon per hour Automatic Water Still, as made by either Barnstead or Stokes. May be for electricity or sewage gas. If for electricity give current characteristics.
1	International Clinical Electric Centrifuge with a 4-place combination head for two 15 ml. tubes and two 50 ml. tubes (give current characteristics).
4	15 ml. graduated resistance-glass conical-bottom centrifuge tubes.
4	50 ml. graduated resistance-glass centrifuge tubes with spouts, E&A 20065/4.
1	5 cu. ft. standard make electric refrigerator.

The approximate cost of the permanent apparatus listed above is $1,110.00.

It is possible to substitute cheaper equipment for some of the items specified, but such substitutions will inevitably result in frequent breakdowns and repairs, and unsatisfactory results. After all, the old axiom that "a workman is as good as his tools" holds good in a sewage plant laboratory as well as in a shop.

The centrifuge listed above is not absolutely necessary, but has been found to be very useful for controlling the drawing-off of supernatant liquor from digestion tanks, and in the operation of activated sludge plants.

Some chemists and plant operators still use colorimetric apparatus for pH determinations. However, a potentiometer, such as the Beckman pH Meter, specified above, is not only more accurate, particularly with sludges, but is also a great time saver to the busy worker.

Minor Equipment Items

This list includes all minor and renewable items such as glassware, brushes, burners, rubber tubing and stoppers, etc. Sufficient glassware is included to allow for reasonable washing intervals.

Quantity	Description
1	Actigel Analytical Balance Desiccator.
1	Fruhling & Shultz Desiccator, 10-inch, with cover and 10-inch Coors porcelain perforated plate.
1	Fruhling & Shultz Desiccator, 8-inch, with cover and 8-inch Coors porcelain perforated plate.
2	Balanced Watch Glasses, 3-inch (1 pair).
	Beakers, No. 1000 Pyrex Griffin low form with lip.
2	1000 ml. capacity
2	600 ml. capacity
4	400 ml. capacity
12	250 ml. capacity
6	100 ml. capacity
4	50 ml. capacity
	Bottles, Narrow Mouth, Flint Glass, round, for corks, AHT 2203, E&A 18652.
12	12 oz. capacity
12	8 oz. capacity
18	300 ml. B.O.D. Bottles, glass-stoppered with stoppers numbered consecutively from 1 to 18 to correspond with numbers on bottles. Numbering to be in black enamel figures. Bottles to be of Non-Sol-Vit glass, and not over 6½" in height, including stoppers. (18 bottles will permit two determinations weekly on raw sewage and effluent.)
	Bottles, Narrow Mouth, glass stoppered tincture, with well ground flat stoppers, AHT 2220 or E&A 18680.
12	1000 ml. capacity
24	500 ml. capacity
12	250 ml. capacity
4	30 ml. Round Dropping Bottles with flat, grooved stoppers, AHT 2257 or E&A 18824.
4	30 ml. Square Dropping Bottles with rubber bulb stoppers and glass pipette E&A 18806.
1	Washing Bottle, 1 liter Pyrex complete with rubber stopper, glass tubes and rubber tubing joints.
4	5-gallon Narrow Mouth Glass Bottles, E&A 18650 (for distilled water).
6	2-gallon Narrow Mouth Glass Stoppered Bottles, AHT 2210-A (for B.O.D. dilution water and standard solutions).
4	1-gallon cider jugs (for compositing and storing samples).
1	Superior quality camel hair brush with wooden handle and ½-in. dia. tuft., AHT 2376 or E&A 19048 (for dusting scale pans).
6	Medium camel hair brushes, AHT 2378 or E&A 19042 (for cleaning watch glasses).
12	Test Tube Brushes with Puff Tuft end, tinned iron wire handle, 1½-inch diameter bristles, AHT 2389.
1	Cylinder Brush, bristle end, strong rattan handle, bristle 2 inches diameter by 4½ inches long, total length 25 inches, E&A 19072.
6	Pipette Brushes, length of bristle 7½ inches, AHT 2382, E&A 19074.
2	Burette Brushes, brass wire handles, tufted bristle end, AHT 2396.
4	Brushes, of black bristle, total length 12 inches, AHT 2363 or E&A 19092.
3	50 ml. Schellbach Burette with large straight glass stopcock, AHT 2436.
1	50 ml. Schellbach Burette with large three-way glass stopcock, AHT 2438.
2	Fisher Burette Supports, complete with clamps, base 7" x 13" Opal White Glass, nickel-plated support rod, E&A 31915.
4	Fisher High Temperature Burners, AHT 2596 or E&A 19309.
4	Apparatus Supports for Fisher Burners, AHT 2599.
6	Clamps, cataloy, cadmium plated with 1½-inch effective jaw opening, E&A 20195.
3	Heffman Pinchcocks, ¾" x 1⅛", AHT 3270, CSC 12195, or E&A 20294.
6	Mohr Pinchcocks, ⅝-inch opening, AHT 3278 or E&A 20298.
2	Test tube Clamps AHT 3246.
	Non-absorbent Cotton (1 pound).
	Corks, first quality, assorted in sizes No. 1 to No. 14, E&A 2119 (1 gross).
	Cork Borers (1 set 3/16 inch to 13/32 inch), AHT 4068, E&A 21213, or CSC 12465.
6	Vitreosil Opaque Fused Silica Dishes, 100 ml. E&A 22000.
3	Vitreosil High Form Opaque Fused Silica Crucibles, without covers, E&A 21248.
24	No. 270 Coors Porcelain Gooch Crucibles, Size No. 3 (25 ml. capacity) without covers.
4	Crucible Holders, Walter, E&A 23050, to fit the filter flasks, Item No. 38.
4	500 ml. No. 5340 Pyrex Filter Flasks.
1	Crucible Tongs, nickel-plated brass, 12 inches long, E&A 32553.
1	Crucible Tongs, nickel-plated brass, 16 inches long, AHT 9701.
1	Crucible Tongs, cast brass, 8 inches long, AHT 9692.
	Cylinders, single graduated Pyrex, AHT 4409, E&A 21652, CSC 16140.
2	1000 ml. capacity
1	500 ml. capacity
6	100 ml. capacity
2	50 ml. capacity
	Whatman No. 2 Filter Paper—15 cm. diameter (6 boxes).
	Grey Filter Paper, 33 cm. diameter, E&A 23156 (* pkgs.).
12	5-inch Triangular Files, AHT 5083.
12	Pyrex Erlenmeyer Flasks, 250 ml. No. 4980.
	Volumetric Flasks, resistance glass with ground glass stop-

pers (two graduations to contain and deliver), AHT 5465.

1 1000 ml. capacity
1 500 ml. capacity
1 250 ml. capacity
1 100 ml. capacity

Funnels, Glass, ground rim and thin stem about 10 cm. long ground to a point, AHT 5570, E&A 23622.

4 6.5 cm. diameter
2 10 cm. diameter.

1 Ribbed-Glass Funnel, 18 cm. O.D. of rim, E&A 23632, AHT 5584.

2 No. 430 Coors Porcelain Evaporating Dishes, Size No. 2, 120 ml. capacity.

12 Glass Stirring Rods, 3/16", E&A 24562.

Glass Tubing, soft glass, regular wall, E&A 24570.
5 mm. O.D. (2 lbs.)
7 mm. O.D. (2 lbs.)
8 mm. O.D. (2 lbs.)

1 No. 520 Coors Porcelain Mortar & Pestle, Size No. 2 (115 mm. inside diameter).

1 No. 550 Coors Porcelain Spot Plate, Size No. 00 (92 x 112 mm.).

1 No. 624 Coors Porcelain Pipette Rest.

No. 650 Coors Porcelain Spatulas.

1 Size 2, 142 mm. long
1 Size 4, 195 mm. long
1 Bottle Cenco Ceramic Marking Ink, CSC 14000.

No. 37000 Exax Blue Line Transfer Pipettes.

2 10 ml. capacity
3 25 ml. capacity
2 50 ml. capacity

No. 37020 Exax Blue Line Mohr-type Measuring Pipettes.

2 1 ml. capacity
2 2 ml. capacity
2 5 ml. capacity
6 10 ml. capacity

1 Pipette Support, revolving, of hardwood, with 3 decks revolving on wooden base, AHT 8264.

Rubber Tubing, Best Heavy White Wall, ½" x ⅛", for automatic still connections, E&A 30683 (12 ft.).

Rubber Tubing, Heavy Red Wall, ⅜" x ⅛", E&A 30703 (12 ft.).

Rubber Tubing, Heavy Red Wall, ¼" x 3/32", E&A 30703 (12 ft.).

Rubber Tubing, ¼" Extra Heavy Vacuum for vacuum pump and aspirator connections, E&A 30710 (12 ft.).

6 Rubber Policemen, 3/16 inch, E&A 30734.

Rubber Stoppers, Solid, No. 3, No. 4, No. 5, No. 6, No. 7, No. 8, No. 9, No. 10, E&A 30639 (1 lb. of each).

Rubber Stoppers, One-Hole, No. 3, No. 4, No. 5, and No. 6, E&A 30641 (½ lb. of each).

Rubber Stoppers, Two-Hole, No. 3, No. 4, No. 5 and No. 6, E&A 30643 (½ lb. of each).

1 Scissors (7-inch), of good quality.
1 Chapman Filter Pump, 5⅜ inches long, AHT 5286, E&A 30134.
1 Test Tube Support, double deck with 24 holes, 22 mm. diameter, with row of pins in rear, AHT 9509 or E&A 31991/1.
2 Spatulas—4-inch stainless steel blades with rosewood handles, E&A 31048.

Thermometers, AHT specifications, AHT 9525.

1 Graduated— 5° C. to 200° C. (for drying oven).
1 Graduated—10° C. to 110° C. (for B.O.D. Incubator).

1 Wood Frame Thermometer, 0-120° F., E&A 32498 (for sewage temperatures).
1 10-inch Maximum and Minimum Thermometer, self-registering, best make—40° F. to 120° F., with magnet, E&A 32416 (for recording outside air temperatures).
24 No. 9800 Pyrex Test Tubes, 150 mm. x 16 mm.
6 Triangles, 2-inch sides, E&A 32648.

Watch Glasses, E&A 32850.

12 3-inch diameter
12 4-inch diameter
12 5-inch diameter

12 5" x 5" Tinned Wire Gauzes with flat asbestos centers, E&A 33090 or AHT 9995.
12 Pencils, all-red wax.
1 4-gallon Stoneware Jar, E&A 25634, AHT 6292 (for waste materials).
1 Gas Diffuser Stones, Aloxite Brand, 1-inch diameter, E&A 24167 (for aerating B.O.D. dilution water).

Gummed Labels, Dennison No. 201, No. 209, No. 217, and No. 223 (2 boxes of each).

1 Hydrometer Cylinder, 2" dia. x 15" high, E&A 21630 (for washing pipettes in cleaning solution).

Iron Rings, combined with fasteners for attaching to iron supports, E&A 30620.

2 1¼-inch I.D.
2 2-inch I.D.
2 3-inch I.D.
2 4-inch I.D.

4 Iron Supports, Medium, 20-inch rod, E&A 31879.
Coarse Glass Wool (E&A 24638), for bottom of hydrometer to prevent breakage of pipettes (4 oz.).

The approximate cost of the minor equipment items listed above is $290.00.

Reagents and Chemicals

All reagents to be chemically pure unless otherwise noted.

Quantity	
5 lbs.	Glacial Acetic Acid, c.p.
6 lbs.	Hydrochloric Acid, Spr. gr. 1.20, c.p.
7 lbs.	Nitric Acid, sp. gr. 1.42, c.p.
1 oz.	Oxalic Acid, c.p. crystal.
18 lbs.	Sulphuric Acid, tech.
9 lbs.	Sulphuric Acid, sp. gr. 1.84, c.p.
1 lb.	Aluminum Sulphate, crystal, c.p.
8 lbs.	Ammonium Hydroxide, sp. gr. 0.90, c.p.
1 lb.	Ammonium Carbonate, c.p.
1 lb.	Asbestos, short fibres, acid washed. Powminco.
5 lbs.	Calcium Chloride, calcined, porous, gran. for desiccators, tech.
1 lb.	Chloroform, pure (Squibb).
1 lb.	Copper Sulphate, crystal, c.p.
1 lb.	Ether, Ethyl, U.S.P.
¼ lb.	Iodine, resublimed, c.p.
1 lb.	Lead Acetate, normal, c.p.
5 lbs.	Manganous Sulphate, c.p.
1 oz.	Methyl Orange Indicator.
1 oz.	Orthotolidine powder, c.p.
1 oz.	Phenolphthalein, c.p.
1 oz.	Potassium Biniodate, c.p.
1 lb.	Potassium Chromate crystals, c.p.
5 lbs.	Potassium Dichromate, tech.
1 lb.	Potassium Dichromate, c.p.
1 lb.	Potassium Hydroxide, pellets, c.p.
2 lbs.	Potassium Iodide, crystal, c.p., Bakers Analyzed Special.
1 lb.	Potassium Oxalate Neutral, c.p.
1 lb.	Potassium Permanganate, crystal, c.p.
1 oz.	Silver Nitrate, c.p.
1 lb.	Soda Lime, 4 to 8 mesh.
5 lbs.	Sodium Bicarbonate, crystal, c.p.
1 lb.	Sodium Carbonate, c.p.
5 lbs.	Sodium Chloride, crystal, c.p.
10 lbs.	Sodium Hydroxide, pellets, c.p.
1 lb.	Sodium Acid Sulphite, $NaHSO_3$, c.p.
4 oz.	Soluble Starch, Indicator Grade.
1 doz.	Litmus Paper, 6 red and 6 blue.
1 oz.	Stopcock Grease.
1 lb.	Sodium Oxalate, c.p.
5 lbs.	Sodium Thiosulphate.
¼ lb.	Thymol (to be used as a preservative for Sodium Thiosulphate Solutions).

One quart of pure Ethyl Alcohol should be purchased locally, as the chemical supply houses are not licensed to supply grain alcohol.

The approximate cost of the reagents and chemicals listed above is $60.00.

Summary of Costs

The approximate cost of furnishing and equipping the complete sewage treatment plant laboratory described above is as follows:

1.	Laboratory Furniture	$1,250.00
2.	Permanent Apparatus	1,110.00
3.	Minor Equipment Items	290.00
4.	Reagents and Chemicals	60.00
	Total Cost	$2,710.00

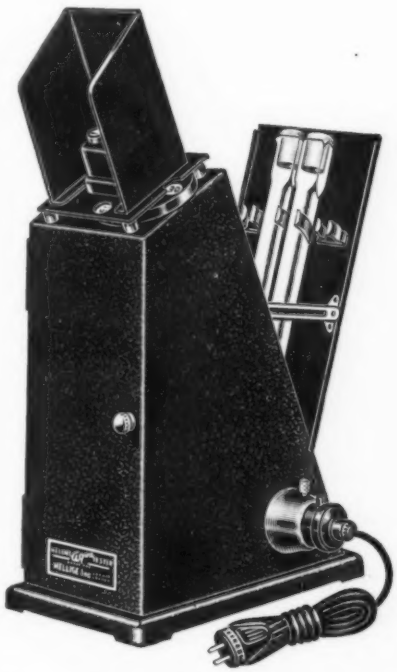
Acknowledgment is given to Mr. Joseph Boreiszo, plant chemist at the Rahway Valley Sewage Treatment Plant, for many helpful suggestions in the preparation of this article.

HELLIGE

INCORPORATED

3718 NORTHERN BLVD., LONG ISLAND CITY, N.Y.

EQUIPMENT FOR THE COLORIMETRIC ANALYSIS OF WATER, SEWAGE, AND INDUSTRIAL WASTES



HELLIGE COLORIMETRIC COMPARATORS employ glass color standards which are non-fading, and therefore permanently reliable. There is no doubt whether these standards are "still good"; there is NO GUESSWORK. Hellige glass color standards never fade or change, never fail. Being made of colored glass, which has, for other uses, maintained its color stability for ages, they are the only standards which can logically carry a lifetime guarantee of accuracy. Glass standards are economical: bought once, they serve for practically an unlimited period, and thus quickly pay for themselves by the saving of time, chemicals, replacement cost, and other expenses encountered in the use of liquid standards. The standards occupy a minimum of space, and are the easiest to manipulate.

The comparators, with which the glass standards are used, are unique in design, and offer more conveniences than any other similar testing outfits. The improved model of Hellige Aqua Tester is shown at the left. The inclined construction for working in a natural sitting position, color fields in juxtaposition, and Nessler tubes with plano-parallel bottom plates are some features of this improved water tester.

The three small illustrations show the Hellige Pocket Comparator. It is the handiest and smallest instrument ever brought on the market for accurate hydrogen ion measurements and water analysis. The durable corrosion-resistant housing holds all parts necessary for a test, as revealed by the left and right hand illustrations which show the comparator with front and rear covers opened. The size of the complete apparatus is only 3¾ x 3¾ x 1½". For both comparators, glass color standards are available for all popular pH indicators, and for the determination of color of water, ammonia nitrogen, nitrate nitrogen, chlorine, iron, dissolved oxygen, manganese, lead, phosphate silica, and sulphides.

The HELLIGE TURBIDIMETER

A Turbidimeter *Without Standards* for Water Analysis and Sulfate Determinations

Illustrations show the observation fields: the one in the center shows the balanced field, after the proper adjustment of the slit by means of the drum knob; the end ones show the unbalanced fields.

This apparatus is based on the comparison of the Tyndall effect on the test liquid with a beam of light passing through the same suspension. Therefore, the use of standard suspensions which are tedious to prepare, and do not retain their original value, is entirely overcome. The comparison fields are distinctly differential so that measurements can be made with utmost convenience, simplicity, and speed, and correct results are obtained by anybody without special training for this type of work. Tubes of different liquid depths are available for turbidity measurements from 0 to 150 p.p.m. SiO_2, and sulfate determinations from 0 to 100 p.p.m. SO_4.

Write today for informative 28-page Bulletin No. 602

EQUIVALENTS AND CONVERSION FACTORS*

The word gallon, used in any conversion factor, designates the U. S. gallon. Likewise, the word ton designates a short ton, 2,000 pounds.

The figures 10^{-1}, 10^{-2}, 10^{-3}, etc., denote 0.1, 0.01, 0.001, etc., respectively.

The figures 10^{1}, 10^{2}, 10^{3}, etc., denote 10, 100, 1000, etc., respectively.

"Parts Per Million," (designated as p.p.m.), is always by weight. As used in the sanitary field, p.p.m. represents the number of pounds of dry solids contained in one million pounds of water. In this field, one part per million may be expressed as 8.345 pounds of dry solids to one million U. S. gallons of water.

Multiply	By	To Obtain
Acres	43,560	Square feet
"	4047	Square meters
Acre-feet	43,560	Cubic feet
" "	325,851	Gallons
" "	1233.49	Cubic meters
Atmospheres	29.92	Inches of mercury
"	33.90	Feet of water
"	76.0	Cms. of mercury
"	14.70	Lbs./sq. inch
Barrels cement	376	Pounds—cement
Bags or sacks-cement	94	Pounds— "
British Thermal Units	777.5	Foot-lbs.
" " "	3.927×10^{-4}	Horse-power-hrs.
" " "	2.928×10^{-4}	Kilowatt-hrs.
" " "	0.2520	Kilogram-calories
" " "	107.5	Kilogram-meters
B.T.U./min.	12.96	Foot-lbs./sec.
" "	0.02356	Horse-power
" "	0.01757	Kilowatts
Centimeters	0.3937	Inches
Centimeters of mercury	0.01316	Atmospheres
" " "	0.4461	Feet of water
" " "	27.85	Lbs./sq. ft.
" " "	0.1934	Lbs./sq. inch
Centimeters/second	1.969	Feet/min.
" "	0.03281	Feet/sec.
" "	0.6	Meters/min.
Cubic centimeters	3.531×10^{-5}	Cubic feet
" "	6.102×10^{-2}	Cubic inches
" "	2.642×10^{-4}	Gallons
" "	10^{-6}	Cubic meters
" "	10^{-3}	Liters
Cubic feet	7.48052	Gallons
" "	1728	Cubic inches
" "	0.03704	Cubic yards
" "	28.32	Liters
" "	2.832×10^{4}	Cubic cms.
" "	0.02832	Cubic meters
Cubic feet/second	0.646317	Million gals./day
" " "	448.831	Gallons/min.
Cubic inches	16.39	Cubic centimeters
" "	5.787×10^{-4}	Cubic feet
" "	1.639×10^{-5}	Cubic meters
" "	4.329×10^{-3}	Gallons
" "	1.639×10^{-3}	Liters
Cubic meters	35.31	Cubic feet
" "	1.308	Cubic yards
" "	264.2	Gallons
" "	10^{3}	Liters
Cubic yards	27	Cubic feet
" "	46.656	Cubic inches
" "	0.7646	Cubic meters
" "	202.0	Gallons
" "	764.6	Liters
Drams	27.34375	Grains
"	0.0625	Ounces
"	1.771845	Grams
Fathoms	6	Feet
Feet	30.48	Centimeters
"	0.3048	Meters
Feet of water	0.8826	Inches of mercury
" " "	0.4335	Lbs./sq. inch
" " "	62.43	Lbs./sq. ft.
" " "	0.02950	Atmospheres
" " "	304.8	Kgs./sq. meter
Feet/sec.	30.48	Centimeters/sec.
" "	18.29	Meters/min.
Foot-pounds	1.286×10^{-3}	British thermal units
" "	5.050×10^{-7}	Horse-power-hrs.
" "	0.1383	Kilogram-meters
" "	3.766×10^{-7}	Kilowatt-hrs.
Foot-pounds/min.	3.030×10^{-5}	Horse-power
" " "	2.260×10^{-5}	Kilowatts
Gallons	0.1337	Cubic feet
"	231	Cubic inches
"	3785	Cubic centimeters
"	3.785×10^{-3}	Cubic meters
"	3.785	Liters
Gallons, Imperial	1.200095	U. S. gallons
" U. S.	0.83267	Imperial gallons
Gallons water	8.3453	Pounds of water
Gallons/min.	2.228×10^{-3}	Cubic feet/sec.
" "	0.06308	Liters/sec.
" "	8.0208	Cu. ft./hr.
Grains (troy)	1	Grains (avoir.)
"	0.06480	Grams
Grains/U.S. gal.	17.118	Parts/million
" /U.S. gal.	142.86	Lbs./million gal.
" /Imp. gal.	14.254	Parts/million
Grams	15.43	Grains
"	0.03527	Ounces
"	980.7	Dynes
Grams/liter	58.417	Grains/gal.
" "	8.345	Pounds/1000 gals.
" "	1000	Parts/million
Hectares	2.471	Acres
Horse-power	42.44	B.T. Units/min.
" "	550	Foot-lbs./sec.
" "	0.7457	Kilowatts
Horse-power (boiler)	33,479	B.T.U./hr.
" " "	9.803	Kilowatts
Inches	2.540	Centimeters
Inches of mercury	1.133	Feet of water
" " "	0.4912	Lbs./sq. inch
" " "	0.03342	Atmospheres
" " "	345.3	Kgs./sq. meter
Inches of water	0.07355	Inches of mercury
" " "	0.03613	Lbs./sq. inch
Kilograms	2.205	Lbs.
Kilograms-calories/min.	51.43	Foot-pounds/sec.
" " "	0.09351	Horse-power
" "	0.06972	Kilowatts
Kgs./sq. meter	3.281×10^{-3}	Feet of water
" " "	1.422×10^{-3}	Lbs./sq. inch
Kilometers	3281	Feet
"	0.6214	Miles
Kilometers/hr.	0.9113	Feet/sec.
" "	27.78	Centimeters/sec.
Kilowatts	56.92	B.T. Units/min.
"	737.6	Foot-lbs./sec.
"	1.341	Horse-power
"	14.34	Kg.-calories/min.
Liters	0.2642	Gallons
"	61.02	Cubic inches
"	0.03531	Cubic feet
Meters	3.281	Feet
"	39.37	Inches
"	1.094	Yards
Miles	5280	Feet
"	1.609	Kilometers
Miles/min.	88	Feet/sec.
" "	1.609	Kilometers/min.
Milligrams/liter	1	Parts/million
Million gals./day	1.54723	Cubic ft./sec.
Miner's inches	1.5	Cubic ft./min.
Ounces	28.349527	Grams
"	437.5	Grains
"	0.9115	Ounces (troy)
Ounces (fluid)	1.805	Cubic inches
" "	29.57	Cubic cm.
Parts/million	8.345	Lbs./million gal.
" "	0.0584	Grains/U. S. gal.
" "	0.07016	Grains/Imp. gal.
Pounds	16	Ounces
"	7000	Grains
"	453.5924	Grams
"	1.21528	Pounds (troy)

*Selections from a booklet of—"Conversion Factors for Engineers"—distributed by The Dorr Co., New York City.

Multiply	By	To Obtain
Pounds of water	0.01602	Cubic feet
" " "	27.68	Cubic inches
" " "	0.1198	Gallons
Pounds/cubic foot	0.01602	Grams/cubic cm.
" " "	16.02	Kgs./cubic meter
" " "	5.787×10^{-4}	Lbs./cubic inch
Pounds/foot	1.488	Kgs./meter
Pounds/inch	178.6	Grams/cm.
Pounds/sq. foot	0.01602	Feet of water
" " "	4.883	Kgs./sq. meter
Pounds/sq. inch	2.307	Feet of water
" " "	2.036	Inches of mercury
" " "	0.06804	Atmospheres
" " "	703.1	Kgs./sq. meter
Quires	25	Sheets
Reams	500	Sheets
Square centimeters	0.1550	Square inches
" "	1.076×10^{-3}	Square feet
Square feet	144	Square inches
" "	0.09290	Square meters
" "	2.296×10^{-5}	Acres
Square inches	6.452	Square centimeters

Multiply	By	To Obtain
Square kilometers	247.1	Acres
" "	10.76×10^{6}	Square feet
" "	1.196×10^{6}	Square yards
Square meters	10.76	Square feet
" "	1.196	Square yards
Square miles	640	Acres
" "	27.88×10^{6}	Square feet
" "	2.590	Square Kilometers
Square yards	9	Square feet
" "	0.8361	Square meters
" "	2.066×10^{-4}	Acres
Tons (long)	1016	Kilograms
" "	2240	Pounds
" "	1.12000	Tons (short)
Tons (metric)	10^{3}	Kilograms
" "	2205	Pounds
Tons (short)	2000	Pounds
" "	907.18486	Kilograms
Tons of water/24 hrs.	0.16643	Gallons/min.
Watts	0.05692	B.T.Units/min.
"	0.7376	Foot-pounds/sec.
"	1.341×10^{-3}	Horse-power
"	0.01434	Kg.-calories/min.
Yards	0.9144	Meters

Relative Carrying Capacities of Pipe Lines of Equal Smoothness

Prepared by Emil L. Neubling for the Reading Meter Repair Co.

Diameter of Pipes	⅛	¼	⅜	½	¾	1	1¼	1½	2	2½
26										348.81
24										285.55
22										229.20
20									316.23	181.02
18									243.00	139.10
16								371.60	181.02	103.62
15								316.23	154.05	88.18
14							419.80	266.13	129.64	74.21
12							285.55	181.02	88.18	50.48
10						316.23	181.02	114.76	55.90	32.00
9						243.00	139.10	88.18	42.96	24.65
8					371.60	181.02	103.62	65.69	32.00	18.32
7					266.13	129.64	74.21	47.05	22.92	13.12
6					181.02	88.18	50.48	32.00	15.59	8.92
5				316.23	114.76	55.90	32.00	20.29	9.88	5.66
4½				243.00	88.18	42.96	24.65	15.59	7.59	4.35
4			371.60	181.02	65.69	32.00	18.32	11.61	5.66	3.24
3½			266.13	129.64	47.05	22.92	13.12	8.32	4.05	2.32
3			181.02	88.18	32.00	15.59	8.92	5.66	2.76	1.58
2½		316.23	114.76	55.90	20.29	9.88	5.66	3.59	1.75	1.00
2		181.02	65.69	32.00	11.61	5.66	3.24	2.05	1.00	
1½		88.18	32.00	15.59	5.66	2.76	1.58	1.00		
1¼	316.23	55.90	20.29	9.88	3.59	1.75	1.00			
1	181.02	32.00	11.61	5.66	2.05	1.00				
¾	88.18	15.59	5.66	2.05	1.00					
½	32.00	5.66	2.05	1.00						
⅜	15.59	2.76	1.00							
¼	5.66	1.00								
⅛	1.00									

Diameter of Pipes	3	3½	4	4½	5	6	7	8	9	10
48			498.83	371.60	285.55	181.02	123.13	88.18	65.69	50.48
46			448.48	334.09	256.73	162.75	110.70	79.10	59.06	45.38
44			401.31	298.96	229.20	145.63	99.29	70.94	52.85	40.61
42			357.25	243.00	204.50	129.64	88.18	63.15	47.05	36.15
40			316.23	235.57	181.02	114.76	78.06	55.90	41.64	32.00
38		388.41	278.17	207.22	159.23	100.94	68.66	49.17	36.63	28.15
36		339.30	243.00	181.02	139.10	88.18	59.98	42.96	32.00	24.65
34		294.12	210.64	156.92	120.58	76.44	51.99	37.24	27.74	21.32
32		252.76	181.02	134.85	103.62	65.69	44.68	32.00	23.84	18.32
30	316.23	215.10	154.05	114.76	88.18	55.90	38.02	27.23	20.29	15.59
28	266.13	181.02	129.64	96.57	74.21	47.05	32.00	22.92	17.07	13.12
26	221.12	150.41	107.72	80.24	61.66	39.09	26.59	19.04	14.18	10.90
24	181.02	123.13	88.18	65.69	50.48	32.00	21.77	15.59	11.61	8.92
22	145.63	99.29	70.94	52.85	40.61	25.74	17.51	12.54	9.34	7.18
20	114.76	78.06	55.90	41.64	32.00	20.29	13.80	9.88	7.36	5.66
18	88.18	59.98	42.96	32.00	24.65	15.59	10.60	7.59	5.66	4.35
16	65.69	44.68	32.00	23.84	18.32	11.61	7.90	5.66	4.21	3.24
15	55.90	38.02	27.23	20.29	15.59	9.88	6.72	4.81	3.59	2.76
14	47.05	32.00	22.92	17.07	13.12	8.32	5.66	4.05	3.02	2.32
12	32.00	21.77	15.59	11.61	8.92	5.66	3.85	2.76	2.05	1.58
10	20.29	13.80	9.88	7.36	5.66	3.59	2.44	1.75	1.30	1.00
9	15.59	10.60	7.59	5.66	4.35	2.76	1.83	1.34	1.00	
8	11.61	7.90	5.66	4.21	3.24	2.05	1.40	1.00		
7	8.32	5.66	4.05	3.02	2.32	1.47	1.00			
6	5.66	3.85	2.76	2.05	1.58	1.00				
5	3.59	2.44	1.77	1.30	1.00					
4½	2.76	1.83	1.34	1.00						
4	2.05	1.40	1.00							
3½	1.47	1.00								
3	1.00									

Diameter of Pipes	12	14	15	16	18	20	22	24	26	28
48	32.00	21.77	18.32	15.59	11.61	8.92	7.03	5.66	4.63	3.85
46	28.77	19.57	16.47	14.02	10.44	8.02	6.32	5.09	4.16	3.46
44	25.74	17.51	14.71	12.54	9.34	7.13	5.66	4.55	3.73	3.10
42	22.92	15.59	13.12	11.16	8.32	6.39	5.04	4.05	3.32	2.76
40	20.29	13.80	11.61	9.88	7.36	5.66	4.46	3.59	2.94	2.44
38	17.84	12.14	10.21	8.69	6.48	4.98	3.92	3.15	2.58	2.17
36	15.59	10.60	8.92	7.59	5.66	4.35	3.43	2.76	2.26	1.83
34	13.51	9.19	7.74	6.58	4.90	3.77	2.97	2.39	1.96	1.62
32	11.61	7.90	6.65	5.66	4.21	3.24	2.55	2.05	1.68	1.40
30	9.88	6.72	5.66	4.81	3.59	2.76	2.17	1.75	1.43	1.19
28	8.32	5.66	4.76	4.05	3.02	2.32	1.83	1.47	1.20	1.00
26	6.91	4.70	3.96	3.37	2.51	1.93	1.52	1.22	1.00	
24	5.66	3.85	3.24	2.76	2.05	1.58	1.24	1.00		
22	4.55	3.10	2.61	2.22	1.65	1.27	1.00			
20	3.59	2.44	2.05	1.75	1.30	1.00				
18	2.76	1.83	1.58	1.34	1.00					
16	2.05	1.40	1.18	1.00						
15	1.75	1.19	1.00							
14	1.47	1.00								
12	1.00									

Diameter of Pipes	30	32	34	36	38	40	42	44	46	48
48	3.24	2.76	2.37	2.05	1.80	1.58	1.40	1.24	1.11	1.00
46	2.91	2.48	2.13	1.85	1.61	1.42	1.26	1.12	1.00	
44	2.61	2.22	1.91	1.65	1.44	1.27	1.12	1.00		
42	2.32	1.97	1.70	1.47	1.28	1.13	1.00			
40	2.05	1.75	1.50	1.30	1.14	1.00				
38	1.81	1.54	1.32	1.14	1.00					
36	1.58	1.34	1.15	1.00						
34	1.37	1.16	1.00							
32	1.18	1.00								
30	1.00									

The foregoing tables will be found useful in proportioning distribution lines.

Example: To find how many one-half inch pipes can be supplied by a 4-in. line, follow down the ½-in. vertical column to the number opposite 4-in. diameter of the first column, where the number 181.02 is found, which is the number of one-half inch lines that can be supplied by a 4-in. line.

Example: To find how many 12-in. lines can be supplied by a 48-in. line, follow horizontally along the 48-in. diameter of the first column, until you reach the 12-in. vertical column, where the number 32 is found, which is the result desired.

CONTENTS OF HORIZONTAL CYLINDERS

A Multiple Use Chart for Vertical as Well as Horizontal Tanks, Pipe Lines, Etc.

By J. TARRANT
Assoc. M. Inst. C. E., A. M. I. Mech. E.
Ruislip (Middlesex), England

THE alignment chart printed herewith gives a convenient method of finding the contents of cylindrical tanks placed with the axis horizontal for all depths of liquid in the tank.

It is usually the case that only a fair approximation of the tank contents is required, and the calculation by exact formula is not very readily done.

Formulas for horizontal cylindrical tanks contents are generally printed in two forms, one for use when the liquid level is above the centre and the other when the level is below the centre of the tank.

On the chart, the scale relating to the depth of liquid is continuous; that is to say, it applies whether the liquid level be in the upper or lower half of the section.

To use the chart, a straightedge is placed across the scales, and the intersections on the three scales give the related values. Line A gives the ratio of depth of liquid to the diameter of the tank; line B, the diameter of the tank in feet; and line C, the contents, in cubic feet and gallons, for each foot of length of the tank. In the example shown by the line across the chart, a tank 15 feet in diameter in which the contents are 10 feet 6 inches deep, will contain approximately 1,000 gallons per foot of length.

By using the fixed value of h/d = 1, the chart also gives contents per foot of height of a cylinder with vertical axis, and also the contents of full pipes per foot of length.

Sometimes the dimensions of a tank or pipe line will not be in feet, but the chart may still be used. The contents will be in units which correspond to the dimensional units, and the scale of gallons will not apply. For example, if the diameter is taken in inches, the contents, *read on the cubic feet scale*, will be in *cubic inches* per *inch* of length.

The calculation of contents is clearly based on the area of the segment of a circle, which is what the contents scale on line C shows, and the calculation of segmental areas, in any dimensional units, may be made by use of the chart so long as the cubic feet scale is read, and units ascribed to this which correspond to the units used for the diameter. When the diameter is in feet, the area of the segment is in square feet; for meters, the area is in square meters; for inches, in square inches, and so on.

WEIGHTS AND MEASURES

Troy Weight

3.086 grains = 1 carat
24 grains = 1 dwt.
20 dwts. = 1 ounce
12 ounces = 1 pound
Used for weighing gold, silver, and jewels.

Apothecaries' Weight

20 grains = 1 scruple
3 scruples = 1 dram
8 drams = 1 ounce
12 ounces = 1 pound
The ounce and pound in this weight are the same as in Troy Weight.

Avoirdupois Weight

1 grain (Troy) = 1 grain (Apoth.) = 1 grain (Avdp.)
27 11/32 grams = 1 dram
16 drams = 1 ounce = 437.5 grains
16 ounces = 1 pound
25 pounds = 1 quarter
4 quarters = 1 cwt.
2,000 lbs. = 1 short ton
2,240 lbs. = 1 long ton
1 long ton = 1 British ton

Dry Measure

2 pints = 1 quart
1 quart = 67.2 cu. in.
1 British bushel = 1.032 U. S. bushel
8 quarts = 1 peck
4 pecks = 1 bushel

Liquid Measure

4 gills = 1 pint
16 fluid ounces = 1 pint
2 pints = 1 quart
4 quarts = 1 gallon
1 British Imperial gallon = 1.200 U. S. gallons
1 cubic foot of water contains 7.48 gallons and weighs 62.321 lb.
1 gallon = 231 cu. in.
31½ gallons = 1 barrel
2 barrels = 1 hogshead

Linear Measure

1 mil = 0.001 inch
12 inches = 1 foot
3 feet = 1 yard
5½ yards = 1 rod
40 rods = 1 furlong
8 furlongs = 1 statute mile
5280 feet = 1 statute mile
3 miles = 1 league

Square Measure

1 circular mil = 0.7854 square mils
1,000,000 square mils = 1 square inch
144 square inches = 1 sq. ft.
9 sq. ft. = 1 sq. yard
4 roods = 1 acre = 43560 sq. ft.
30¼ sq. yds. = 1 sq. rod
40 sq. rods = 1 rood
640 acres = 1 sq. mile

Surveyor's Measure

7.92 inches = 1 link
25 links = 1 rod
4 rods = 1 chain
10 sq. chains or 160 sq. rods = 1 acre
36 sq. miles (6 miles square) = 1 township
43560 sq. ft. = 1 acre
640 acres = 1 sq. mile

Mariners' Measure

6.08 feet = 1 fathom
120 fathoms = 1 cable length
8.31 cable lengths = 1 nautical mile
6080 feet = 1 nautical mile
1 nautical mile = 1.15 statute mile
1 knot is a speed of 1 nautical mile per hour

Paper Measure

24 sheets = 1 quire
20 quires = 1 ream
2 reams = 1 bundle
5 bundles = 1 bale

Cubic Measure

1 cu. cm. = .061 cu. in.
27 cu. ft. = 1 cu. yd.
40 cu. ft. = 1 ton (shipping)
231 cu. in. = 1 standard gallon
2150.42 cu. in. = 1 standard bushel
1 cu. ft. = 4/5 of a bushel
1728 cu. in. = 1 cu. ft.
128 cu. ft. = 1 cord (wood)

Household Measure

60 drops = 1 teaspoon
2 teaspoons = 1 dessert spoon
3 teaspoons = 1 tablespoon
16 tablespoons = 1 cup
2 gills = 1 cup
2 cups = 1 pint

METRIC EQUIVALENTS

Linear Measure

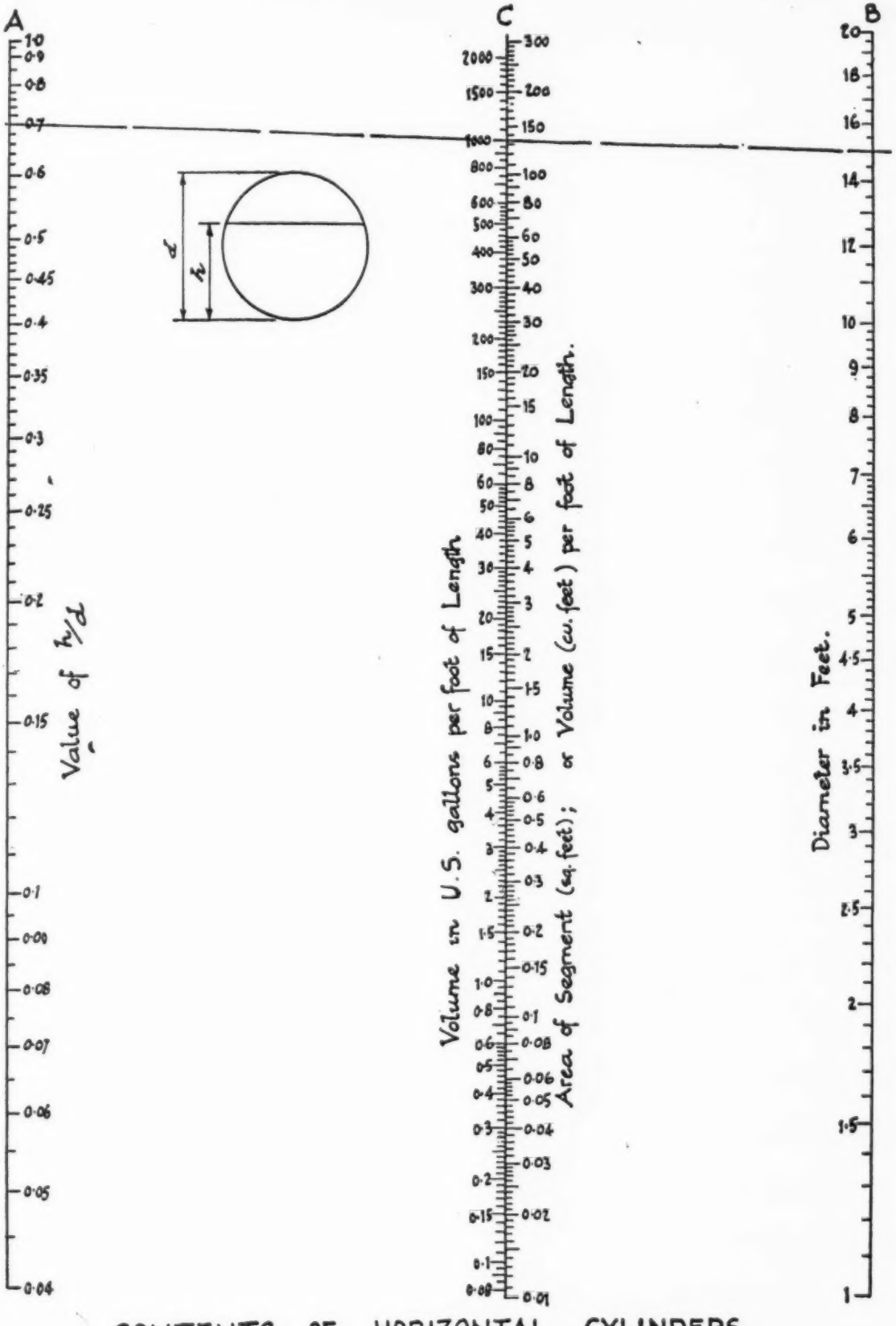
1 millimeter = 0.03937 inches
1 centimeter = 0.3937 inches
1 decimeter = 3.937 in. = 0.328 ft.
1 meter = 39.37 in. = 1.0936 yards
1 dekameter = 1.9884 rods
1 kilometer = 0.62137 mile
1 inch = 2.54 centimeters
1 foot = 3.048 decimeters
1 rod = 0.5029 dekameter
1 yard = 0.9144 meter
1 mile = 1.6093 kilometers

Square Measure

1 sq. cm. = 0.1550 sq. in.
1 sq. decimeter = 0.1076 sq. ft.
1 sq. meter = 1.196 sq. yds.
1 hectare = 2.47 acres
1 sq. kilometer = 0.386 sq. miles
1 sq. in. = 6.452 sq. cm.
1 sq. foot = 9.2903 sq. decimeters
1 sq. yard = 0.8361 sq. meter
1 sq. mile = 2.59 sq. kilometers

Weights

1 dyne = .00102 grains
1 gram = 0.03527 ounces
1 kilogram = 2.2046 lbs.
1 metric ton = 2205 lbs.
1 pound = 0.4536 kilograms
1 metric ton = 1.1023 short tons
1 ounce = 28.35 grams = 437.5 grains

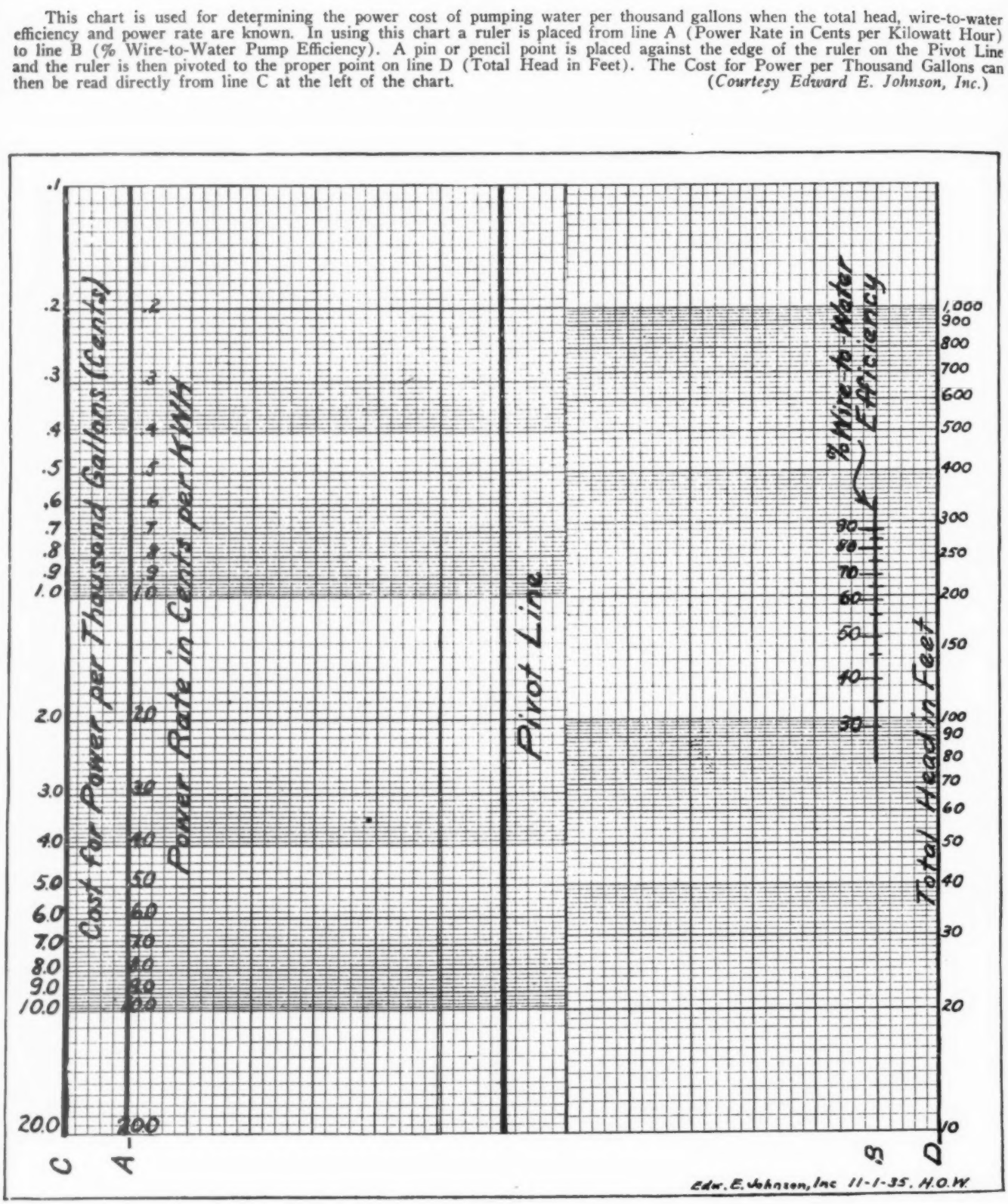


CONTENTS OF HORIZONTAL CYLINDERS.

Copyright 1942: J. Tarrant, Assoc. M. Inst. C.E., A.M.I. Mech. E.

CHART FOR DETERMINATION OF PUMPING COSTS

This chart is used for determining the power cost of pumping water per thousand gallons when the total head, wire-to-water efficiency and power rate are known. In using this chart a ruler is placed from line A (Power Rate in Cents per Kilowatt Hour) to line B (% Wire-to-Water Pump Efficiency). A pin or pencil point is placed against the edge of the ruler on the Pivot Line and the ruler is then pivoted to the proper point on line D (Total Head in Feet). The Cost for Power per Thousand Gallons can then be read directly from line C at the left of the chart. *(Courtesy Edward E. Johnson, Inc.)*



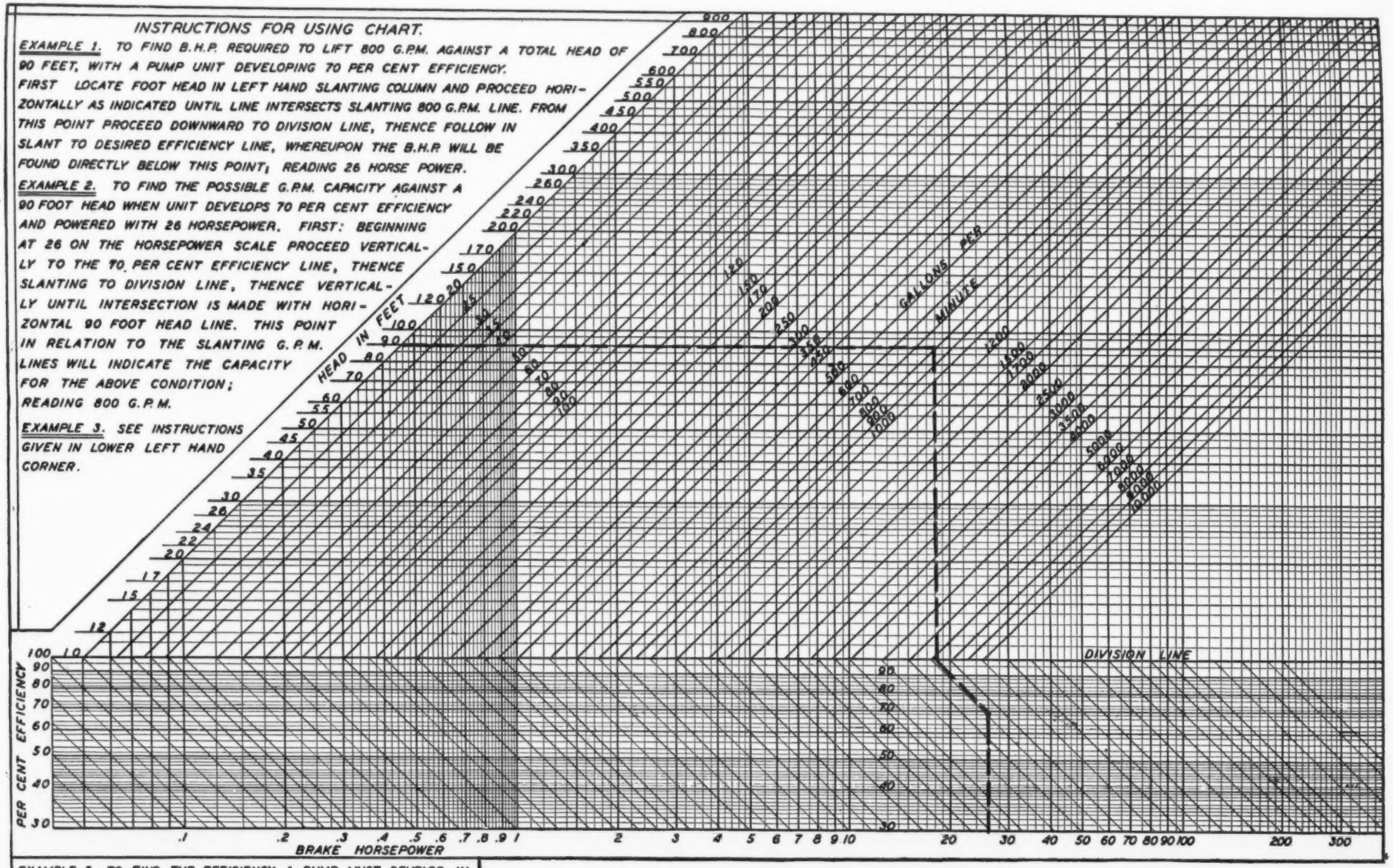
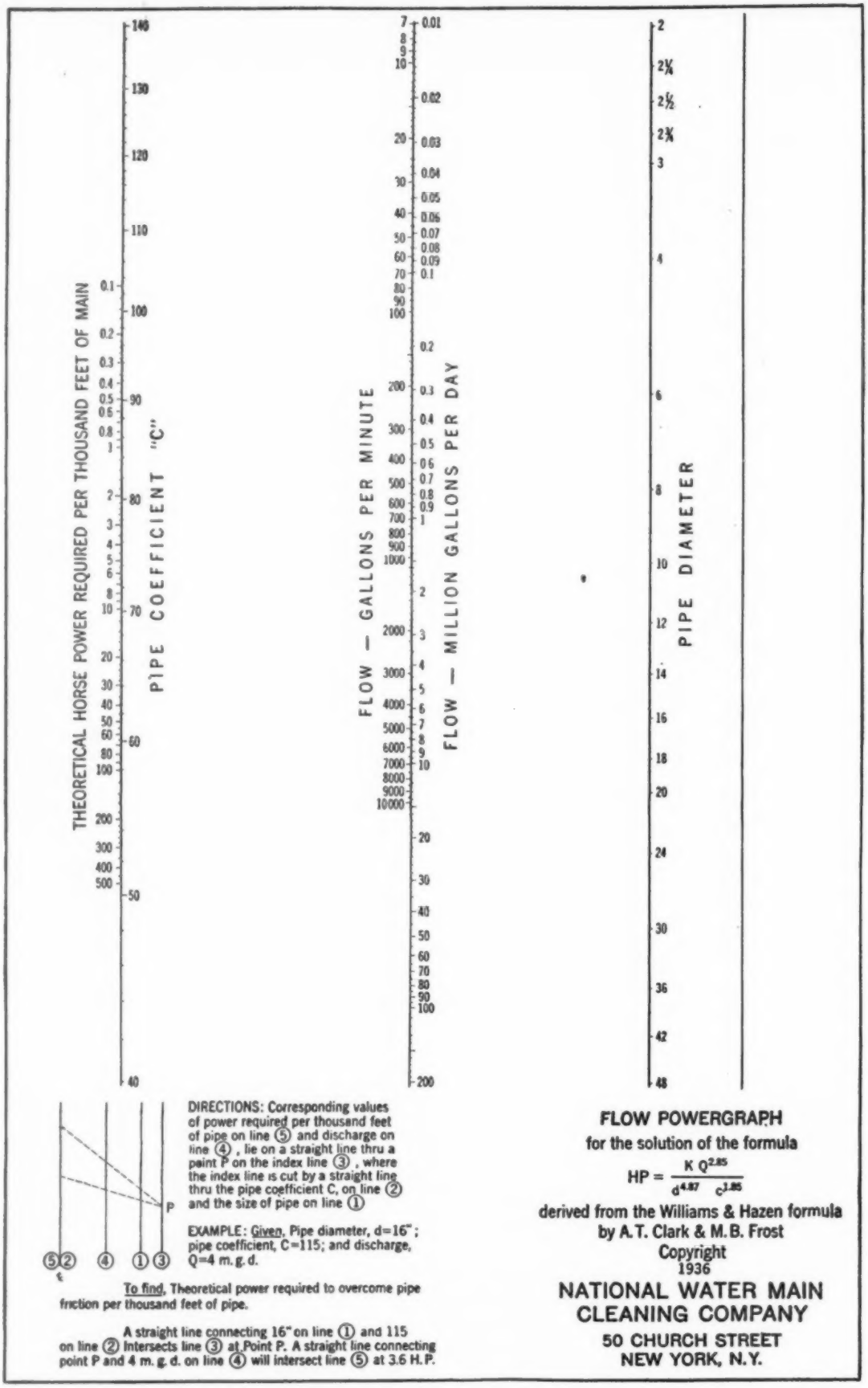

INSTRUCTIONS FOR USING CHART.
EXAMPLE 1. TO FIND B.H.P. REQUIRED TO LIFT 800 G.P.M. AGAINST A TOTAL HEAD OF 90 FEET, WITH A PUMP UNIT DEVELOPING 70 PER CENT EFFICIENCY. FIRST LOCATE FOOT HEAD IN LEFT HAND SLANTING COLUMN AND PROCEED HORIZONTALLY AS INDICATED UNTIL LINE INTERSECTS SLANTING 800 G.P.M. LINE. FROM THIS POINT PROCEED DOWNWARD TO DIVISION LINE, THENCE FOLLOW IN SLANT TO DESIRED EFFICIENCY LINE, WHEREUPON THE B.H.P. WILL BE FOUND DIRECTLY BELOW THIS POINT; READING 26 HORSE POWER.
EXAMPLE 2. TO FIND THE POSSIBLE G.P.M. CAPACITY AGAINST A 90 FOOT HEAD WHEN UNIT DEVELOPS 70 PER CENT EFFICIENCY AND POWERED WITH 26 HORSEPOWER. FIRST: BEGINNING AT 26 ON THE HORSEPOWER SCALE PROCEED VERTICALLY TO THE 70 PER CENT EFFICIENCY LINE, THENCE SLANTING TO DIVISION LINE, THENCE VERTICALLY UNTIL INTERSECTION IS MADE WITH HORIZONTAL 90 FOOT HEAD LINE. THIS POINT IN RELATION TO THE SLANTING G.P.M. LINES WILL INDICATE THE CAPACITY FOR THE ABOVE CONDITION; READING 800 G.P.M.
EXAMPLE 3. SEE INSTRUCTIONS GIVEN IN LOWER LEFT HAND CORNER.
HEAD IN FEET
GALLONS PER MINUTE
DIVISION LINE
PER CENT EFFICIENCY
BRAKE HORSEPOWER
EXAMPLE 3. TO FIND THE EFFICIENCY A PUMP MUST DEVELOP IN ORDER TO DELIVER 800 G.P.M. AGAINST A 90 FOOT HEAD WITH 26 HORSEPOWER. PROCEED AS IN EXAMPLE 1 TO DIVISION LINE, THEN SLANTWISE UNTIL INTERSECTION IS MADE WITH THE VERTICAL 26 HORSEPOWER LINE. THIS POINT WILL LOCATE THE HORIZONTAL EFFICIENCY LINE; READING 70 PER CENT.

Chart for Determining Head, Capacity, Efficiency, Horse Power With Any Three Conditions Known

(From the Peerless Pump Bulletin)

Flow Powergraph


THEORETICAL HORSE POWER REQUIRED PER THOUSAND FEET OF MAIN
PIPE COEFFICIENT "C"
FLOW — GALLONS PER MINUTE
FLOW — MILLION GALLONS PER DAY
PIPE DIAMETER
DIRECTIONS: Corresponding values of power required per thousand feet of pipe on line ⑤ and discharge on line ④, lie on a straight line thru a point P on the index line ③, where the index line is cut by a straight line thru the pipe coefficient C, on line ② and the size of pipe on line ①
EXAMPLE: Given, Pipe diameter, d=16"; pipe coefficient, C=115; and discharge, Q=4 m.g.d.
To find, Theoretical power required to overcome pipe friction per thousand feet of pipe.
A straight line connecting 16" on line ① and 115 on line ② intersects line ③ at Point P. A straight line connecting point P and 4 m.g.d. on line ④ will intersect line ⑤ at 3.6 H.P.
FLOW POWERGRAPH
for the solution of the formula
$HP = \frac{K\,Q^{2.85}}{d^{4.87}\ C^{1.85}}$
derived from the Williams & Hazen formula
by A.T. Clark & M.B. Frost
Copyright
1936
NATIONAL WATER MAIN CLEANING COMPANY
50 CHURCH STREET
NEW YORK, N.Y.

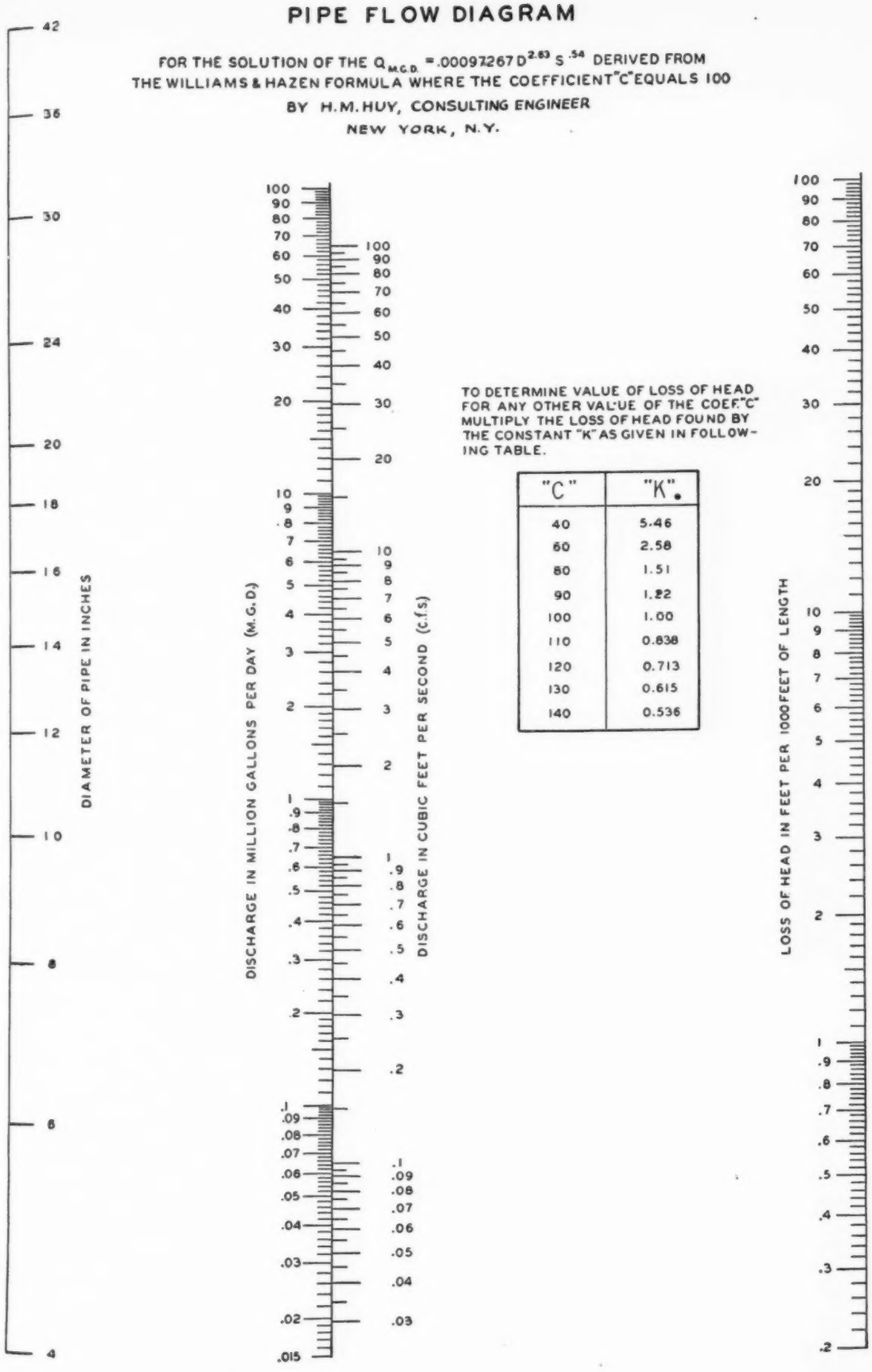
This Highly Useful Graph Was Devised by Arthur T. Clark and M. B. Frost for Simplified Determination of Power Required to Overcome Pipe Friction Under Various Conditions. Also to Determine Condition of Pipe Lines in Service. (Copies of This Graph on Linen Are Being Distributed Gratis by National Water Main Cleaning Co., New York City.)

PIPE FLOW DIAGRAM

FOR THE SOLUTION OF THE $Q_{M.G.D.} = .00097267\,D^{2.63}\,S^{.54}$ DERIVED FROM THE WILLIAMS & HAZEN FORMULA WHERE THE COEFFICIENT "C" EQUALS 100

BY H. M. HUY, CONSULTING ENGINEER

NEW YORK, N.Y.


DIAMETER OF PIPE IN INCHES
DISCHARGE IN MILLION GALLONS PER DAY (M.G.D.)
DISCHARGE IN CUBIC FEET PER SECOND (c.f.s.)
LOSS OF HEAD IN FEET PER 1000 FEET OF LENGTH

TO DETERMINE VALUE OF LOSS OF HEAD FOR ANY OTHER VALUE OF THE COEF. "C" MULTIPLY THE LOSS OF HEAD FOUND BY THE CONSTANT "K" AS GIVEN IN FOLLOWING TABLE.

"C"	"K".
40	5.46
60	2.58
80	1.51
90	1.22
100	1.00
110	0.838
120	0.713
130	0.615
140	0.536

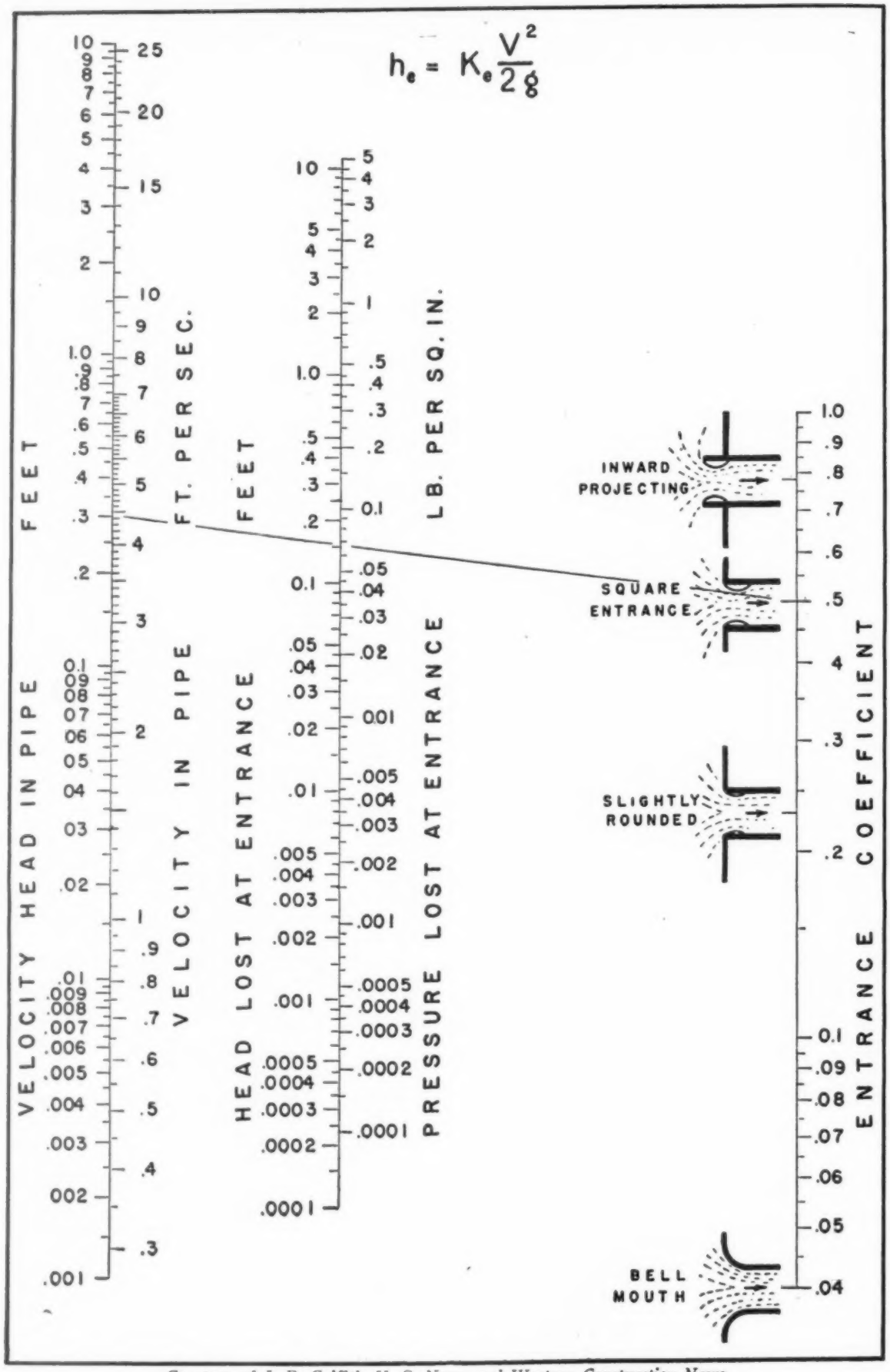
(b) **FRICTION COEFFICIENT "C":** Determine hydrant discharge rate (M.G.D.) at the end of a section of pipe line. Take simultaneous pressure readings at non-flowing hydrants on the same line several hundred feet ahead. Correct all pressure readings for difference in elevations of gages and calculated friction head loss per 1,000 ft. of intervening pipe*. From flow rates observed and known pipe diameter, follow Example (a) to obtain loss of head which would have resulted with coefficient at "C100." This figure divided into the actual (observed) loss of head reveals the "K" factor and from the useful "C-K" table the coefficient "C" can be approximated. *(Accuracy depends upon use of tested pressure gages, careful flow measurements, and inducing a large loss of head between the non-flowing hydrants. For procedure in making hydrant flow tests, see article by Wilson elsewhere in this Section.)

Directions for Application of This Diagram

(a) **FRICTION HEAD LOSS:** A line run from pipe diameter (left vertical) through M.G.D. rates of flow (center) intersects friction vertical (right) to reveal computed friction loss per 1,000 ft. of pipe line; or pressure required per 1,000 ft., in pumping, to overcome such loss due to friction at corresponding line capacity. (If the friction coefficient, due to greater roughness or smoothness of the pipe walls, is other than the base used ["C=100"], multiply the head loss obtained by the corresponding "K" factor given for various "C" values in the "C-K" table on the chart.)

(This diagram is reproduced through courtesy of H. M. Huy and permission of Hydraulic Development Corp. At a location earlier in this Data Section "Practical Methods of Making Flow Tests at Hydrants" are described by P. S. Wilson.)

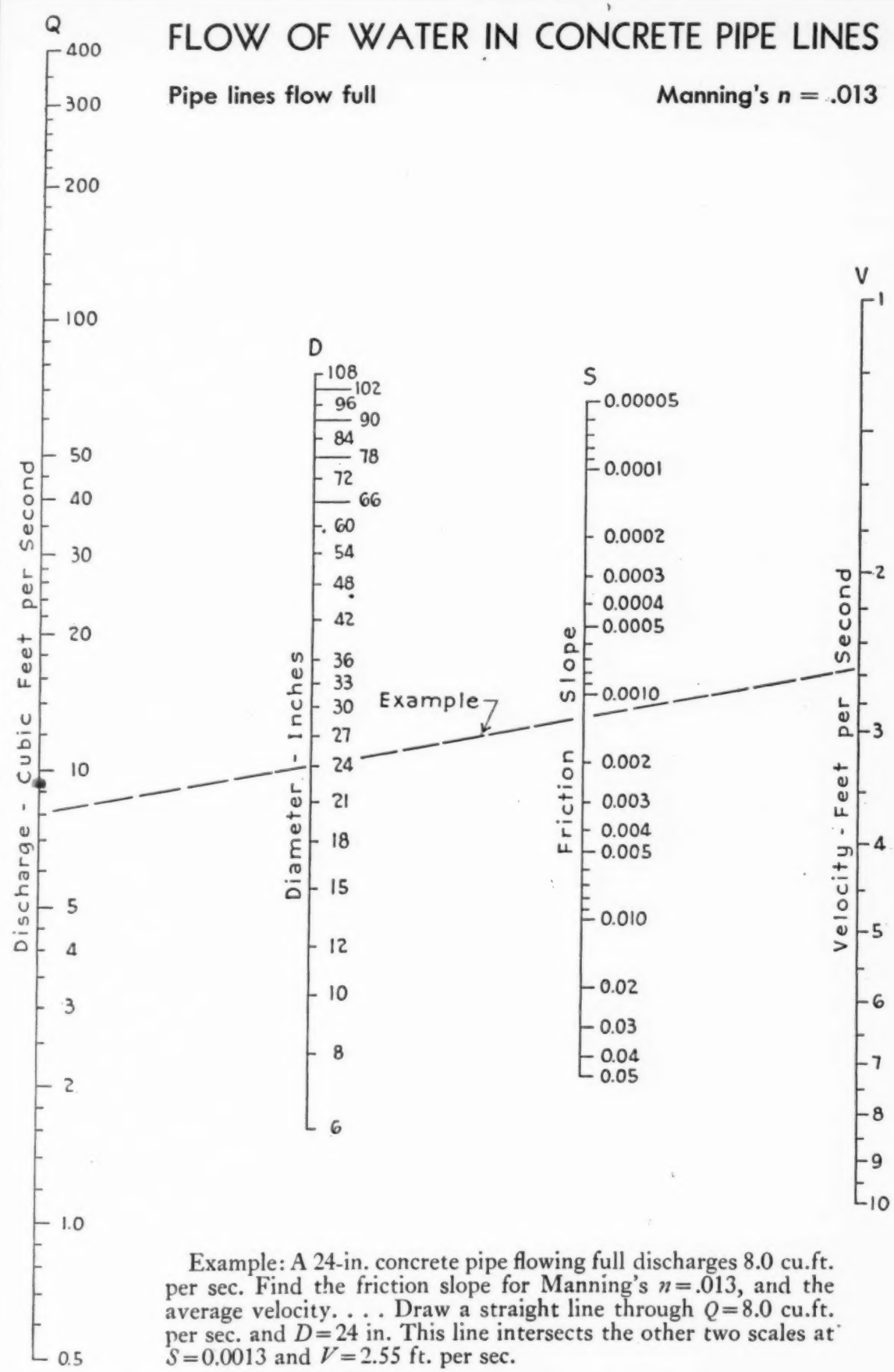
HYDRAULIC ENTRANCE LOSSES



Courtesy of J. R. Griffith, U. S. Navy, and Western Construction News.

FLOW OF WATER IN CONCRETE PIPE LINES

Pipe lines flow full **Manning's n = .013**



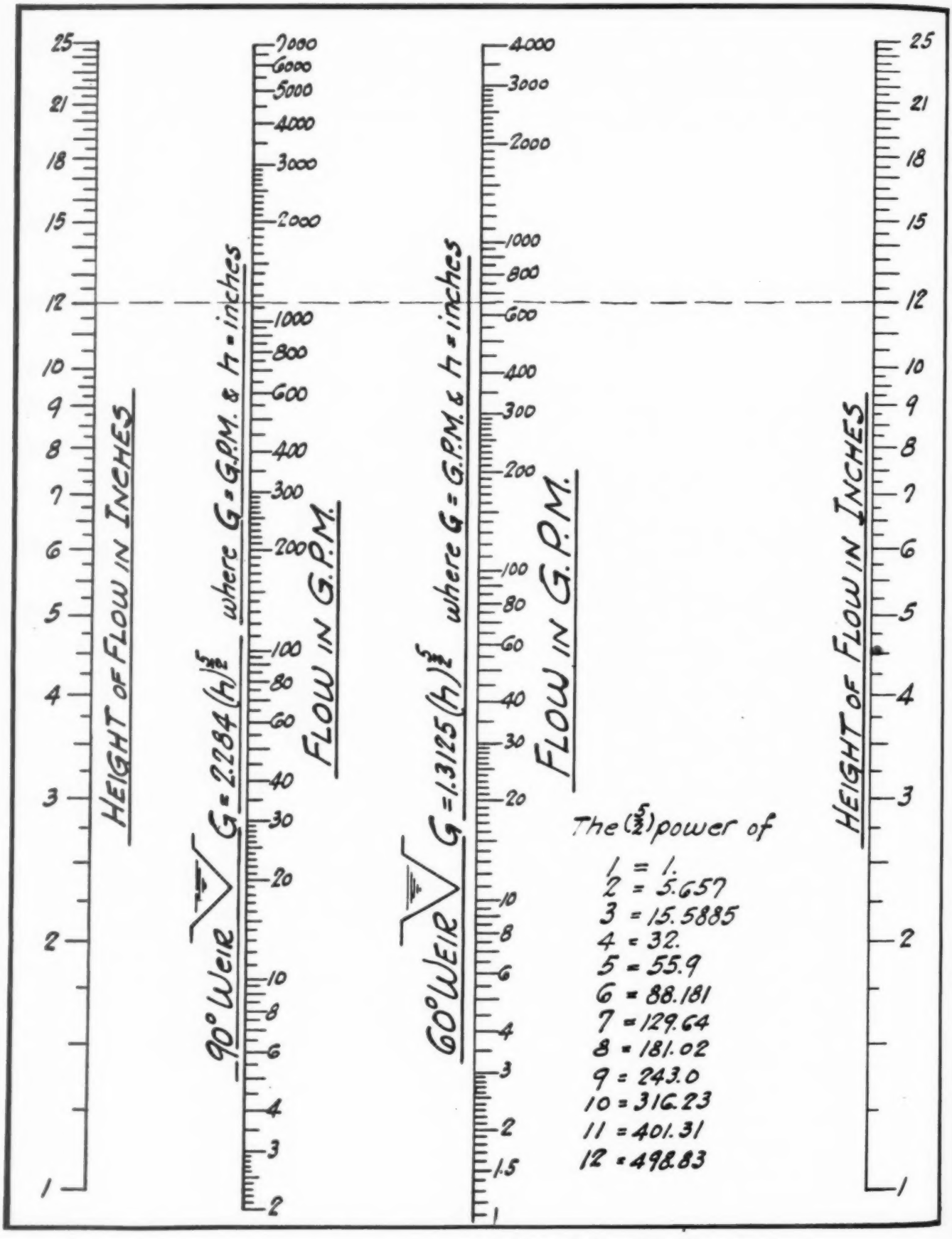
Example: A 24-in. concrete pipe flowing full discharges 8.0 cu.ft. per sec. Find the friction slope for Manning's n=.013, and the average velocity. . . . Draw a straight line through Q=8.0 cu.ft. per sec. and D=24 in. This line intersects the other two scales at S=0.0013 and V=2.55 ft. per sec.

FLOWS THROUGH CONCRETE PIPE

**Methods of constructing this type of chart are explained in detail in "The Construction of Nomographic Charts," by F. T. Mavis. Published by International Textbook Company, Scranton, Pa., 1939.*

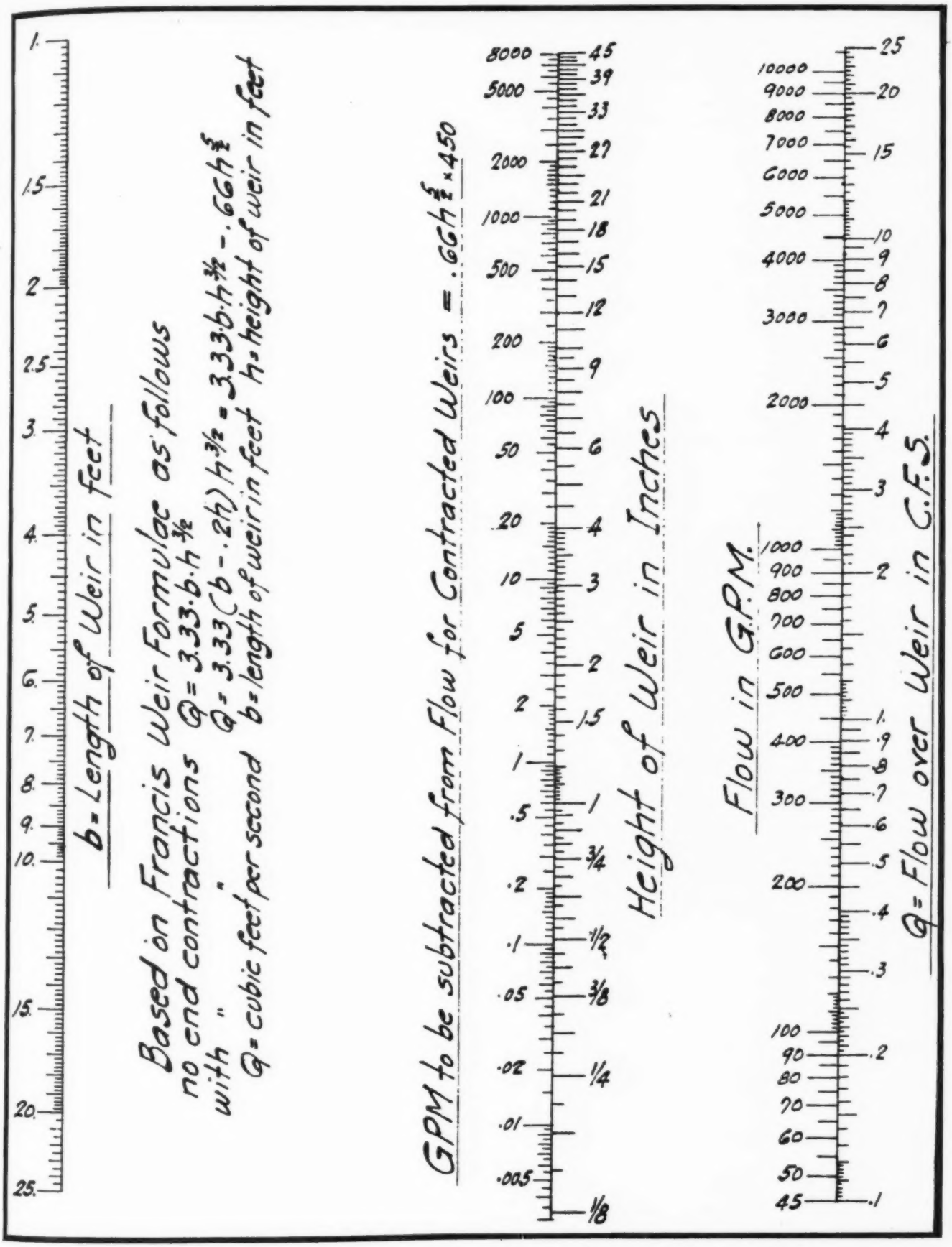
A chart constructed by Dr. F. T. Mavis, head Dept. of Civil Engineering, Penna. State College and appearing with the chapter "Flow of Water In Pipe Lines" by Professor J. E. Christiansen, University of California, written for "Concrete Pipe Lines," published by the American Concrete Pipe Association, 1942.

CHART FOR CAPACITY OF 60° AND 90° V-NOTCH WEIRS


HEIGHT OF FLOW IN INCHES
90° WEIR
G = 2.284 (h)^5/2 where G = G.P.M. & h = inches
FLOW IN G.P.M.
60° WEIR
G = 1.3125 (h)^5/2 where G = G.P.M. & h = inches
FLOW IN G.P.M.
HEIGHT OF FLOW IN INCHES
The (5/2) power of
1 = 1.
2 = 5.657
3 = 15.5885
4 = 32.
5 = 55.9
6 = 88.181
7 = 129.64
8 = 181.02
9 = 243.0
10 = 316.23
11 = 401.31
12 = 498.83

Courtesy of Roberts Filter Mfg. Co., Darby, Pa.

CHART FOR CAPACITY OF RECTANGULAR WEIRS


b = Length of Weir in feet
Based on Francis Weir Formulae as follows
no end contractions Q = 3.33·b·h^3/2
with " Q = 3.33(b - .2h) h^3/2 = 3.33·b·h^3/2 - .66h^5/2
Q = cubic feet per second b = length of weir in feet h = height of weir in feet
GPM to be subtracted from Flow for Contracted Weirs = .66h^5/2 × 450
Height of Weir in Inches
Flow in G.P.M.
Q = Flow over Weir in C.F.S.

Courtesy of Roberts Filter Mfg. Co., Darby, Pa.

CALCULATION OF AREAS, VOLUMES, SURFACES REDUCED TO SIMPLE TERMS

Mensuration is arithmetic applied to geometry in determining the length of lines, the area of surfaces, and the volume of solids or bodies.

Definitions of geometrical terms, figures and principles. A point (.) has position only. A line (———) has length only. Area has length and breadth. A solid has length, breadth and thickness. Parallel means extended in the same direction, and equidistant at all points. Horizontal means parallel with water level; vertical or perpendicular, parallel with plumb line; diagonal, obliquely across a polygon. (Fig. 4) Equilateral means, having equal sides. Quadrilateral, having four sides. An angle (Fig. 1) is formed by two straight lines diverging from a commont point called the vertex. A right angle (Fig. 2) is formed by two straight lines meeting perpendicularly. An oblique angle is either (acute—Fig. 1) smaller, or (obtuse—Fig. 3) greater than a right angle.

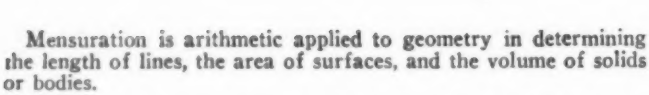


Fig. 1. Fig. 2. Fig. 3. Fig. 4. Rectangle. Parallel Lines.

A plane or plane figure has area or surface only—perfectly even.

A polygon is a plane figure having three or more equal sides.

A triangle is a plane figure bounded by three straight lines.

An equilateral triangle (Fig. 6) has all of its (3) sides equal. An isosceles triangle (Fig. 7) has two of its sides equal. A scalene triangle (Fig. 5) has none of its sides equal. The base is the side on which a geometrical figure is supposed to stand. The least distance between the base and the opposite angle dotted line (Fig. 7) or between parallel lines (Fig. 8) is called the perpendicular or altitude.

To find the area of a triangle. Rule—Multiply base by the altitude and take half of the product. Or, when the three sides are given. From half of the sum of the three sides, subtract each side separately; then multiply the half sum and the three remainders together and extract the square root. Find sq. ft. in a triangle, base 8 ft., altitude 9 ft.

Fig. 5. Fig. 6. Fig. 7.

Answer—$(8 \times 9) \div 2 = 36$.

A parallelogram is a plane figure, bounded by four straight lines, whose opposite sides are equal, as a rectangle, a square, and a rhomboid.

A rectangle is a right angled parallelogram. A square is an equilateral rectangle. A rhomboid is an oblique angled parallelogram.

To find the area of a parallelogram. Rule—Multiply the length by the width.

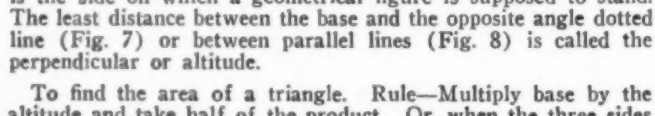


Fig. 8. Rhomboid. Trapezoid. Trapezium. Square

How many sq. ft. in a rectangle 17 by 24?

Answer—$17 \times 24 = 408$ sq. ft.

In a (square) floor 10 by 10?

Answer—$10 \times 10 = 100$ sq. ft.

Note—Dividing the area of a rectangle by one side gives the other side—if unknown.

A *trapezoid* is a quadrilateral having two of its sides parallel. To find its area. Rule—Multiply its average length by the width.

How many sq. yd. in a garden whose parallel sides are 60 and 80 yd., and width 52 yd.?

Answer—$(60 + 80 \div 2) = 70$; then, $70 \times 52 = 3{,}640$ sq. yd.

A *trapezoid* is a quadrilateral having two of its sides parallel.

To find its area. Rule—Form two triangles by a diagonal line, then multiply diagonal by sum of perpendiculars and take half of product.

Find sq. rods in field shaped like a trapezium, whose diagonal is 90 rods, and perpendiculars (25 and 40) 65 rd.

Answer—$90 \times 65 = 5850 \div 2 = 2925$ rd.

A *rightangled triangle* has one right angle. Its longest side is called hypotenuse, and the other two, base and perpendicular or altitude. To find its area. Rule—Multiply the base by the perpendicular and take half of the product.

How many square rods in a triangular field whose base is 70 rods and the perpendicular, 48 rods?

Answer — $(70 \times 48) \div 2 = 1680$ square rods.

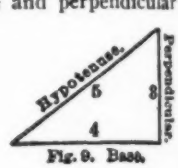


Fig. 9. Base.

Properties of the rightangled triangle. The square of the hypotenuse equals the sum of the squares of the base and the perpendicular. From this principle — illustrated by Fig. 10—we derive the following rules.

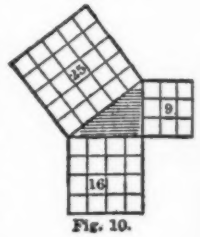


Fig. 10.

To find the hypotenuse. Rule—Add the square of the base and the square of the perpendicular, and of the sum extract square root.

A and B start from the same point, A going 4 miles due west and B, 3 miles due north; how far apart are they then?

$4^2 = 16$
$3^2 = 9$
$\sqrt{25} = 5$

Answer—5 miles.

The square of 4 (base)$=16$; of 3 (perpendicular)$=9$; the square root of their sum $(25)=5$, the hypotenuse.

To find the base or perpendicular. Rule—From the square of the hypotenuse, subtract the square of the other given side, and of their difference extract the square root.

Find the perpendicular of a triangular field whose hypotenuse is 75 rods, base 60 rods.

$75^2 = 5625$
$60^2 = 3600$
$\sqrt{2025} = 45$

Answer—45 rods.

Note—To find the difference between the squares of two numbers, simply multiply their sum by their difference.

To find the side of a square equal in area to any given quantity. Rule—Extract the square root of the given quantity.

Thus, the dimensions of a square field containing 4000 square rods must be $(\sqrt{4000} = 63.246)$ 63¼ rods, nearly. Proof: $63\frac{1}{4}^2 = 4000+$

To find the diagonal of a square. Rule—Multiply one side of the square by 10, diminish the product by 1% of itself and divide remainder by 7.

What is the diagonal of a field 35 rods square?

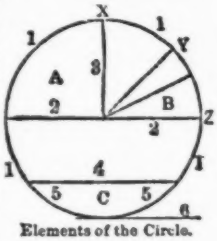
$35 \times 10 = 350$,
1% of $350 = 3.5$
$7)\overline{346.5}$
Ans. (rd.) 49.5

This is a simple way of finding the hypotenuse of a triangle whose base and perpendiculars are equal.

The Circle

A circle is a plane figure bounded by a curved line, (1. 1, 1, 1) called circumference, every point of which is equally distant from

the center. The diameter is a straight line (2, 2) across a circle, through its center. The radius is a straight line (3) from the center to the circumference. An arc is any part of the circumference (5, 5). A chord, a straight line (4) joining ends of an arc. A tangent (6) touches circum. without cutting it. A segment is space (C) enclosed by arc and chord. A sector, space (B) enclosed by two radii and arc. A quadrant (A) is 90° or the fourth part of circle. A circle is divided into 360°; from X to Y is 45°; from X to Z, 90°. A sextant is one-sixth of a circle.



Elements of the Circle.

To find the *circumference* of a circle, the diameter being given. Rule—Multiply the diameter by 3 1/7; for greater accuracy, by 3.1416.

Find circumference of bicycle wheel; diam. 28 in.

Answer—$28 \times 3\,1/7 = 88$ in.

To find the *diameter* of a circle, the circumference being given. Rule—Divide the circumference by 3 1/7, or multiply it by .3183.

Circumference of a tree 144½ in., find diam.

Answer—$144.5 \times 3183 = 46$ in.

To find the *area* of a circle. Rule—Multiply the square of the diameter by .7854; or the square of the radius by 3.1416; or the square of the circumference by .07958.

Find the area of a piston 20 in. in diam.

Answer—$20^2 \times .7854 = 314.16$ sq. in.

Over how many sq. ft. can a cow graze, staked to a rope 50 ft. long? Here, 50 feet is the radius.

Answer—$50^2 \times 3.1416 = 7854$ sq. ft.

To find the *radius* of a circle, the area being given. Rule—Multiply the area by .3183 and extract the square root of the product.

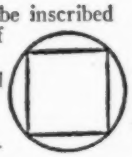
Find length of halter, tied to stake, that will enable horse to graze on 1 acre.

Answer—Square feet in acre, $43560 \times .3183 = 13865$; $\sqrt{13865} = 117¾$ ft. long.

Note—The circumference of a circle is 3.1416 times greater than the diameter. The number 3.1416 (called Pi); its reciprocal, .3183; its 4th part .7854, its 6th part .5236, and others, should be committed to memory as they are indispensable factors in computing the areas and volumes of circular figures and bodies.

To find the *area of a sector* of a circle. Rule—Take such a part of the circle as the degrees in the given arc, are part of 360. Thus, a sector whose arc is 40°, contains 40/360 or 1/9 of the area of the circle.

To find the side of the greatest square that can be inscribed in a given circle. Rule—Multiply the diameter of the circle by .707; or the circumference by .225.



The diameter of a log is 24 inches; how large a sill can be cut from it?

$24 \times .707 = 17$ in. square, nearly.

To inscribe the greatest equilateral triangle. Rule—Multiply the diameter of the circle by .886.

Side of greatest inscribed hexagon equals the radius of a circle.

To find the diameter of a circle that will inscribe a given square. Rule—Multiply the side of the desired square by 1.414.

What must be diam. of a log to cut a sill 12 in. sq.?

Answer—$12 \times 1.414 = 17$ in.

The area of the greatest square inscribed in a given circle is exactly ½ of the area of the least square circumscribed about the same circle—or the square of its diameter.

To find the area between the two *concentric circles*. Rule—Take the difference between the area of each circle. A simpler way is to multiply the sum of the two diameters by their difference, and the product by .7854.

Find the area included between two concentric circles whose diameters are 30 and 50 inches. (80, sum; 20, dif.)

Answer—$20 \times 80 = 1600 \times .7854 = 1256.64$ sq. in.

To find the diameter of a circle whose area is equal to the area of a given square. Rule—Multiply one side of the given square by 1.1284.

To find the side of a square whose area is equal to the area of a given circle. Rule—Multiply the diameter of the given circle by .8862.

To find the diameter of three greatest equal circles that can be inscribed in a given circle. Rule—Multiply the diameter of the given circle by .464.

Find the diameters of the three greatest circles that can be inscribed in a circle 50 in. in diam.

Answer—$50 \times .464 = 23.2$ in.

An *ellipse* is a plane figure bounded by an oval curved line and has a long and a short diameter or axis.

To find its circumference. Rule—Multiply the sum of the two diameters by 3.1416, and take half of the product.

Ellipse.

Find the circumference of an ellipse whose diameters are .41 and 29 ft.

$(41 + 29) = 70 \times 3.1416 \div 2 = 110$ ft. nearly.

To find the *area of an ellipse*. Rule—Multiply the product of the two diameters by .7854.

How many square ft. are there in an elliptical platform whose diameters are 60 and 40 ft.?

$60 \times 40 = 2400 \times .7854 = 1885$ sq. ft. nearly.

Polygons

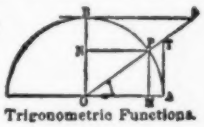
Triangle. Square. Pentagon. Hexagon. Octagon.

To find the area of polygons, having equal sides and equal angles. Rule—Multiply the square of one of the equal sides—of a triangle, by .433; of a pentagon, by 1.7205; of hexagon, by 2.5981; of octagon, by 4.8284.

One side of an equilateral triangle is 30 inches, and of an octagon, 10 in.

Find sq. in. in each.

$30^2 \times 433 = 389.7$ in. T; $10^2 \times 4.824 = 482.84$ in. O.


Trigonometric Functions.

For the benefit of those who intend to study trigonometry and surveying, this illustration is inserted here. It will be an advantage and saving of time to be already familiar with the terms and the functions of the science when beginning its study.

P M, sine.
O M, cosine.
A T, tangent.
B S, cotangent.
O T, secant.
O S, cosecant.
M A, versed sine.
B N, conversed sine.

Cubes, Cones, Pyramids, Spheres,

A *cube* is a solid body, having six equal square sides. To find its area. Rule—Multiply area of one side by 6. To find its volume. Multiply the length, the breadth and the thickness together.

Cube.

Find sq. in. in surface of a 12 in. cube.

Answer—$12^2 \times 6 = 864$.

How many cubic in. in a cubic foot?

Answer—$*12^3 = 1728$.

Find cu. ft. in a cu. mile.

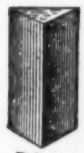
Answer—$5280^3 = 147197952000$.

A *parallelopiped* is a solid body whose six faces are all rectangles. To find its area. Rule—Add areas of its six sides. To find its volume. Same as the cube. How many cubic feet in a wagon bed 10½ feet long, 3 ft. wide and 1¼ ft. deep?

Parallelopiped.

Answer—$10½ \times 3 \times 1¼ = 39⅜$.

A *prism* is a solid having three or more rectangular sides, whose ends or bases are parallel plane figures. To find its area. Rule—Add areas of the sides and ends. To find its volume. Multiply the area of one end by the length.


Prism.

Find the area of a triangular prism, each of whose three sides are 10 by 25 inches.

Answers—836.6 sq. in.

$10^2 \times .433 \times 2 = 86.6$ sq. in. in area of the two ends.

$10 \times 25 \times 3 = 750$ sq. in. area of sides. $86.0 + 750 = 836.6$.

How many cubic inches in above prism, 10 by 25 inches?

Answer—$10^2 \times .433 = 43.3 \times 25 = 1082½$ cu. in.

A *globe* or *sphere* is a solid body, bounded by a uniformly curved surface. To find its area. Rule—Multiply the square of diameter by 3.1416; or the square of the circumference by .3183. To find its volume. Multiply the cube of diameter by .5236.

Globe.

How many square in. in the surface; and how many cubic in. in the volume of a globe 12 in. in diameter?

Answer—904.78 cu. in. $12^2 \times 3.1416 = 452.39$ sq. in. $12^3 \times .5236 = 904.78$ cu. in.

How many cubic miles in the earth, its diameter being nearly 8000 miles?

Answer—$2000^3 \times .5236 = 268083200000$ cubic mi.

Find greatest cube inscribed in a 26 in. globe.

Answer—$26 \times .577 = 15$ in.

To find the dimensions of a cube, equivalent in volume to a given globe. Rule—Multiply the diameter of given globe by 806.

To find the diameter of a globe, equivalent in volume to a given cube. Rule—Multiply one side of the cube by 1.2407.

A *cylinder* is a round body of uniform diameter whose ends are parallel plane figures. To find its area. Rule—Multiply the circumference by the length and to the product add the areas of both ends. To find its volume. Multiply the area of one end by length.

Cylinder.

Find the area of a cylinder 30 inches in circumference and 40 inches long.

Answer—1343.24 sq. in.

$30 \times 40 = 1200$ sq. in. in convex surface.

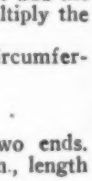
$30^2 \times .07958 \times 2 = 143.24$ sq. in. in the two ends.

Find cubic in. in a cylinder, diameter, 20 in., length 50 in.

Answer—$20^2 \times .7854 \times 50 = 15708$ cu. in.

A *cone* is a solid, which has a circular base and tapers uniformly to a point called vertex.

A *pyramid* is a solid, resembling a cone, having three or more triangular sides.


Cone.

Pyramid.

To find the area of a *cone or pyramid*. Rule—Multiply the circumference or perimeter of the base by the slant height, and to half of the product, add the area of the base.

Find the area or surface of a cone whose circumference at base is 40 in., and slant height 50 in.

Answer—1127.33 sq. in.

$50 \times 40 \div 2 = 1000$ sq. in. in convex surface.

$40^2 \times .07958 = 127.33$ in. base.

To find the volume of a cone or pyramid. Rule—Multiply the area of the base by the height and take ⅓ of the product.

How many cubic feet in a 6 sided pyramid, 10 ft. high, whose perimeter, at base is 15 ft. or each side 2½ ft.?

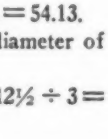
Answer—54.13 cu. ft.

$2\frac{1}{2}^2 \times 2.598 = 16.24$, area of base. $10 \times 16.24 \div 3 = 54.13$.

Find cu. in. in a cone whose height is 12½ in., and diameter of base 10 in.

Answer—$10^2 \times .7854 = 78.54$ area of base. $78.54 \times 12\frac{1}{2} \div 3 = 32.25$ cu. in.

The solid contents of the cone, globe, cylinder and the cube, all of equal dimensions, are in the ratio of 1, 2, 3 and 3.82 respectively. Thus, taking 1 foot as the height and the diameter; the cone contains .2618; the globe .5236, and the cylinder .7854 of a cubic foot. The cube equals 1 cu. ft.



The *frustum of a cone or pyramid* is the part which remains after cutting off the top, parallel to the plane of the base. To find the area of a frustum. Rule—Multiply the sum of circumferences, or perimeters, by the slant height, and to half of the product, add the area of each base.

Frustums.

Find the *area of a frustum* of a cone, whose slant height is 40 in., its greater circumference, 30 in., and its smaller one, 10 in.

Answer—879.58 sq. in.

$30 + 10 \times 40 \div 2 = 800$, sides. $30^2 + 10^2 \times .07958 = 79.58$, area of bases.

To find the *volume of any frustum*. Rule—Square both ends of one side, if angular, or the diameters of both ends or bases, if round. To the two squares add the product of the given ends or diameters; ⅓ of this sum will be the area of the average base of the frustum of a square pyramid, which multiplied by .7854 equals area of average base of frustum of a cone; multiplied by .433, of a three sided frustum, by 1.7205, of a five sided fr., by 2.5981, of a six sided frustum, by 4.8284, of an eight sided frustum. For volume: multiply average area by perpendicular height.

Find the volume or capacity of a round tank whose diameter is 15 ft. at base, 12 ft. at top, and 10 ft. deep. Ans.—14.37 cu. ft.

$12^2 = 144$
$15^2 = 225$
$12 \times 15 = 180$

$183 \times .7854 = 143.73$ sq. ft., area of av. base of Fr. of cone.

3)549(183, area of av. base of F. of sq. pyr.

$143.73 \times 10 = 1437.3$ cu. ft. $\times 7.48 = 10751$ gallons.

Find sq. ft. of lumber in a wagon tongue; large end, 4½ in. sq., small end, 2½ in., length, 9 ft. (108 in.).

Answer—$4\frac{1}{2} + 2\frac{1}{2}^2 + (4\frac{1}{2} \times 2\frac{1}{2}) \div 3 = 12\,7/12$ sq. in., area of average base; $12\,7/12 \times 108 = 1359$ cu. in. $\div 144 = 9\,7/16$ sq. ft.

How many cu. ft. in a straight log, whose diameter at large end is 3 ft., small end, 2 ft., length 12 ft?

Answer—$3^2 + 2^2 + (3 \times 2) \div 3 \times .7854 = 4.974$ sq. ft., area of average base; $4.974 \times 12 = 59.69$ cu. ft.

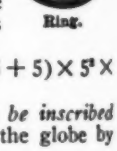
A *spheroid* or elongated globe has a fixed and a revolving axis. To find its area. Rule—Multiply the revolving axis by the fixed axis, and that product by 3.1416. To find its volume. Rule—Multiply the square of the revolving axis by the fixed axis and that product by .5236. Find area, also the volume of spheroid; revolving axis, 20 in., fixed, 30 in.

Spheroid

$20 \times 30 \times 3.1416 = 1884.96$ sq. in. in area.

$20^2 \times 30 \times .5236 = 6283.2$ cu. in. in volume.

A *cylindrical ring* is formed by bending a cylinder. To find its area. Rule—Multiply sum of inside diam. and thickness of ring, by thickness, and the product by 9.87. To find its volume. Rule—Multiply sum of inside diam. and thickness by square of thickness, and product by 2.467.


Ring.

Find the area, also the volume of a ring whose inner diameter is 15 inches, and whose thickness is 5 inches.

$(15 + 5) \times 5 \times 9.87 = 987$ sq. in. in area. $(15 + 5) \times 5^2 \times 2.467 = 1233.5$ cu. in vol.

To find the dimensions of *greatest cube that can be inscribed in a given globe*. Rule—Multiply the diameter of the globe by .577.

The above material has been drawn from "Ropp's Calculator"—an extremely useful and inexpensive little booklet published by C. Ropp & Sons, of Chicago.

CONSOLIDATED REFERENCE AND DATA INDEX
1941 through 1947

All subjects in this and previous issues are listed with the respective key,—('41), ('42), ('43), ('44), ('45), ('46), or ('47)

A

A-B-C of Depreciation ..... ('47) Mag. 237
Accounted for Water and Unbilled Revenue ..... ('45) R-109
Accounting Practices, Municipal Depreciation ..... ('45) R-15
Accounts, Joint Water and Sewer ..... ('46) R-177
Accurate Levelling and Aligning by Simp'e Method ..... ('45) R-46
Acid, Inhibited, for Removing Encrustations ..... ('46) R-241
Activated Carbon ..... ('47) R-135
Activated Sludge—
Air Distribution System ..... ('44) R-205
Bulking ..... ('42) R-202, R-203, ('45) R-212, ('46) R-225
Chlorination for Sludge Index Control ..... ('47) R-199
Density Control ..... ('47) R-197
Diffused Air Plant Operation ..... ('44) R-211
Diffuser Media ... ('43) R-265, ('44) R-221, ('46) R-230, ('47) R-201
Index Test ..... ('44) Mag. 222
Mechanical Aeration ..... ('45) R-203
Plant Operation ..... ('44) R-211, ('47) R-191
Process ..... ('45) R-197
Thickening ..... ('43) R-243
Activated Sludge Bulking ..... ('42) R-203, ('46) R-225
Activated Sludge Thickening ..... ('43) R-243
Administration of Joint Water and Sewer Accounts ..... ('46) R-177
Aero-chlorination of Sewage ..... ('43) R-211
Air and Chlorine for Degreasing Sewage ..... ('43) R-211
Air, Compressed, for Main Cleaning ..... ('47) R-81
Air, Compressed, Flushing of Small Mains ..... ('46) R-55
Air, Compressed, for Dewatering Mains ..... ('46) R-48
Air Diffuser Plate Cleaning ..... ('46) R-238, ('47) R-201
Air Diffuser Plate Purging with Chlorine ..... ('44) R-221
Air Diffuser, Porous, Servicing ..... ('46) R-230
Air Distribution Systems for Activated Sludge Plants ..... ('44) R-205
Air-Gas Mixtures, Limits of Flammability ..... ('46) R-201
Air Leak Costs ..... ('47) R-200
Air-Lift Subaqueous Trencher ..... ('45) R-116
Air Release for Sewage Pumps ..... ('45) R-256
Air Sniffer Corrects Pump Pounding ..... ('46) R-84
Algae Control ..... ('44) R-127, ('46) R-173, ('47) R-118
Aligning and Leveling Method ..... ('45) R-46
Alkalinity Effect on pH ..... ('46) R-275
Alkalinity, pH, and CO_2 Relations ..... ('46) R-274
All Purpose Pipe Chart ..... ('46) Mag. 160
Altitude, Effect of on Pumps ..... ('46) R-161
A Lubrication Check Sheet ..... ('46) R-213
Ammonia, Anhydrous ..... ('41) R-117
Ammoniation, Aqua ..... ('41) R-95
Analyses of Water, Interpretation of ..... ('46) R-148
Analyses, Sewage and Effluent ..... ('42) R-250
An Employee Profit Sharing Plan of a Municipally Owned Water Utility ..... ('46) Mag. 143
Anhydrous Ammonia ..... ('41) R-117
Anthrafilt and Its Significance ..... ('45) R-145
Apparatus for Collecting Flocculated Samples ..... ('46) R-141
Application of Cathodic Protection to Sewage Plant Equipment ..... ('46) R-235
Application of Copper Sulfate ..... ('45) R-119
Application of the Sludge Index Test to Plant Operation ..... ('44) Mag. 222
Aqua Ammoniation ..... ('41) R-95
Aquatic Vegetation and Micro-organisms, Control of ..... ('44) R-127
Area of Cylinder Surfaces ..... ('47) R-237
Areas of Circles, Squares, Roots ..... ('46) R-269
Areas, Volumes, Surfaces, Calculation of ..... ('47) R-274
Arsenite-Ortho-Tolidine Test, Direct Reading ..... ('46) R-167
A Small Meter Repair Shop ..... ('46) R-121
A Useful All Purpose Pipe Chart ..... ('46) Mag. 160
Automatic Operation of Centrifugal Pumps ..... ('46) R-78
A Vacuum Filter Dressing Rig ..... ('42) R-242

B

Bacteriological Procedure, Simplified for Water Examination ..... ('46) R-171
Balls, Rubber Beach, for Sewer Cleaning ..... ('43) R-182
Basic Factors in the Pollution of Sub-surface Water ..... ('46) R-24
Beach Balls for Sewer Cleaning ..... ('43) R-182
Bed, Filter, Maintenance ..... ('43) R-155
Bells, Suction, Submergence and Spacing of ..... ('46) R-83
Bending Pipes ..... ('46) R-77
Bicarbonate Alkalinity, Effect on pH ..... ('46) R-275
Bids Pump, Method of Evaluation ..... ('46) R-86
Biofiltration System ..... ('41) R-189
Blotting Out Waste ..... ('47) R-93
Blowing Out Service Lines ..... ('47) R-99
Books on Water and Sewage Works Problems ..... ('46) R-13
Bottoms, Filter, Porous Plate ..... ('46) R-139
Branches, Number and Size Main Will Supply ..... ('47) R-38
Brass and Copper Pipe, Capacity, and Pressure Drop Through ..... ('45) R-276
Brassert Automatic Self Cleaning Strainers ..... ('42) R-114
Break-point Chlorination ..... ('47) R-159
Buildings, Regulating Water Piping Within ..... ('45) R-19
Bulking, Activated Sludge ..... ('42) R-203, '46) R-225
Bulking Control, Activated Sludge ..... ('45) R-212
Bulking, Control of Activated Sludge ..... ('42) R-202
Bushings, Pipe from Standard Pipe ..... ('47) R-69

C

Calculating Inclined Diagonal Pipe Runs ..... ('46) R-68
Calculation of Areas, Volumes, Surfaces Reduced to Simple Terms ..... ('47) R-274
Calgon Treatment ..... ('45) R-151
Capacities, Carrying, Relative for Pipe Lines ..... ('47) R-263
Capacity and Pressure Drop, Brass and Copper Pipe ..... ('45) R-276
Capacity, Carrying of Sewer Pipe ..... ('46) R-266
Capacity, Head, Efficiency, Horsepower ..... ('47) R-267
Capacity, Maintenance of Water Well ..... ('47) R-109
Capacity of Cylindrical Tanks ..... ('47) R-32
Capacity of Reciprocating Pumps (Nomograph) ..... ('42) R-274
Capacity of Rectangular Weirs, Chart of ..... ('47) R-273
Capacity of 60° and 90° Weirs ..... ('47) R-272
Capacity of Well Recovered with Chlorine ..... ('47) R-112
Carbon, Activated ..... ('45) R-125
Carbonate Alkalinity Effect on pH ..... ('46) R-275
Carbon Feeder, Practical ..... ('46) R-175
Care and Maintenance of Gate Valves ..... ('47) R-84
Carrying Capacity of Pipe Lines ..... ('47) R-263
Carrying Capacity of Sewer Pipe ..... ('46) R-266
Casings, Cleaning Meter, by Sand Blasting ..... ('46) R-124
Cast Iron Mains, Lining in Place with Cement Mortar ..... ('45) R-96
Cast Iron Pipe Cutting ..... ('44) R-75, ('47) R-91
Cathodic Protection ..... ('43) R-83
Cathodic Protection in Mechanical Sewage Filters ..... ('46) R-235
Cathodic Protection in Sludge Digester Part Corrosion ..... ('46) R-242
Cathodic Protection of Steel Surfaces in Contact with Surfaces ..... ('45) R-67
Caulking of Pipe Joints, Pneumatic ..... ('47) R-89
Causes of Activated Sludge Bulking ..... ('46) R-225
Cavitation in Pumps ..... ('46) Mag. 125
Cement Lining Distribution Systems ..... ('46) R-51
Cement Mortar Lining of Mains in Place ..... ('45) R-96
Centrifugal Pump Conservation ..... ('44) R-63
Centrifugal Pump Peculiarities ..... ('46) R-75
Centrifugal Pumps (See Pumps) ..... ('44) R-59, ('47) R-21
Centrifugal Pumps, Automatic Operation of ..... ('46) R-78
Centrifuging for Determination of Suspended Solids ..... ('45) R-262
Centrifuging to Determine Sludge Solids ..... ('41) R-222
Centriline Process for Lining Pipe Lines ..... ('46) R-51
Change Gear, Gage for Meter ..... ('47) R-111
Channel, Rectangular, Flow ..... ('46) R-272
Characteristics of Natural Waters ..... ('46) R-146
Charges for Industrial Waste, Special Sewer Service ..... ('44) R-166
Chart for Capacity of Rectangular Weirs ..... ('47) R-273
Chart for Capacity of 60° and 90° V-Notch Weirs ..... ('47) R-272
Chart for Converting Grains per Gallon to Pounds per Million and the Reverse ..... ('47) R-120
Chart for Determination of Equivalent Pipes ..... ('47) R-42
Chart for Determination of Pumping Costs ..... ('47) R-266
Chart for Determining Head, Capacity, Efficiency and Horsepower ..... ('47) R-267
Chart for Determining Per Cent Sludge Digestion ..... ('46) R-256
Chart for Dry Chemical Feeders, Checking ..... ('45) R-154
Chart, Friction for Valves and Fittings ..... ('47) R-52
Chart of Loss of Head in Feet per 1000 Ft. of Pipe ..... ('44) R-28, ('46) R-268
Charts for Determining Equivalent Pipes and Loop Flow Distribution ..... ('45) R-83
Charts in Sewage Works Operation ..... ('47) R-249
Checking Chart for Dry Chemical Feeders ..... ('45) R-154
Checking Pump Efficiencies ..... ('44) R-59
Checking Tuberculation by Chloramine Treatment ..... ('46) R-57
Checking Water Hammer ..... ('46) R-113
Check Sheet, Lubrication ..... ('46) R-213
Check Sheet, Pump Trouble ..... ('46) R-85

REFERENCE AND DATA INDEX — 1941 through 1947

All subjects in this and previous issues are listed with the respective key,—('41), ('42), ('43), ('44), ('45), ('46), or ('47)

Checks on Water Works Operation, Guides and....('46) R-15
Check Valve Slam, Elimination of....('46) R-112
Chemical Analyses of Water, Interpretation of....('46) R-148
Chemical Feeder, Inexpensive....('47) R-246
Chemical Feeders, Checking Chart for Dry....('45) R-154
Chemical Treatment of Soapy Waste Waters....('46) R-253
Chemical Weed Control....('47) R-121
Chemicals, Weights per Cu. Ft. of Dry....('47) R-64
Chloramine Treatment, Checking Tuberculation by....('46) R-57
Chlorination (See Also—Chlorine)—
Chloramine Treatment....('46) R-57
Manganese Removal by....('47) R-159
Practices, Contemporary....('47) R-131
Sewage, Control of....('47) R-243
Sludge Index Control....('47) R-199
Chlorine—
Aero- ....('43) R-211
Cleaning Filters With....('45) R-159
Control of Act. Sludge Bulking....('45) R-212
Critical Problem Solved by....('47) R-55
Cylinder Carriage....('46) R-145
Demand, Determination of....('45) R-240
Handling ....('47) R-127
Handling and Use ....('47) Mag. 253
Ice Problem....('47) R-129
Institute Manual....('47) Mag. 256
Liquid ....('46) R-142
Purging of Diffuser Plates....('44) R-221
Recovers Well Capacity....('47) R-112
Residual, Test for....('45) R-133
Chlorine Demand Determination, The....('45) R-240
Chlorine Dioxide Treatment of Water....('45) R-129
Chlorine Solves A Critical Problem....('47) R-55
Chloro-aeration for Degreasing of Sewage....('43) R-211
Circles, Squares, and Roots....('46) R-269
Circular Channel Flow....('45) Mag. 201
Circular Orifice for Flow Measurement....('46) R-39
Circular Sewer Flow....('46) R-270
Classified Index of Products....('47) R-2
Clay Sewer Pipe, Velocity and Discharge in....('42) R-193
Cleaning Air Diffuser Plates, Dry....('46) R-238
Cleaning Air Diffusion Media....('47) R-201
Cleaning and Cement Lining Distribution System....('46) R-51
Cleaning and Rehabilitating Wells....('47) R-107
Cleaning Encrusted Pipe Lines and Vacuum Filters with Inhibited Muriatic Acid....('46) R-241
Cleaning Filters with Chlorine....('45) R-159
Cleaning Filters with Sulphur Dioxide....('46) R-135
Cleaning Lime Solution Lines....('45) R-241
Cleaning Mains with Compressed Air....('47) R-81
Cleaning, Mechanical Sewer....('47) Mag. 251
Cleaning Meter Casings by Sand Blasting....('46) R-124
Cleaning, Painting, and Protecting Steel Water Tanks..('45) R-64
Cleaning Pipe, Use of Inhibitors in....('46) R-161
Cleaning Sewers....('46) R-192
Cleaning Sewers with Rubber Beach Balls....('43) R-182
Cleaning, Water Main....('47) R-78
"C" Line for Friction Losses....('46) R-37
CO_2, Alkalinity and pH Relations....('46) R-274
Coagulation Aid by Colloidal Silica....('44) Mag. 211
Coagulation with Ferric Salts....('46) Mag. 147
Coefficients, Friction, Pipe Line....('42) R-59
Coils or Rolls, Length of Material in....('44) R-184
Collecting Flocculated Samples....('46) R-141
Collection and Washing Grit....('41) R-156
Collection of Joint Water and Sewer Accounts....('46) R-177
Colloidal Silica as an Aid to Floc Formation....('44) Mag. 211
Columns, Safe, from Standard Pipes....('47) R-170
Combustion Engines, Internal, Fume Trap for....('46) R-20
Commercial Pipe Sizes for Fire Streams....('46) R-64
Compress Air, Dewatering Mains with....('46) R-48
Compressed Air Flushing of Small Mains....('46) R-55
Compressed Air, Main Cleaning with....('47) R-81
Compressed Air Speeds Pipe Cutting....('44) R-111
Compressed Air to Clear Corroded Service Lines....('43) R-113
Computing Horsepower from Revolving Watt-Hour Meters....('46) R-114
Concentric Orifices....('46) Mag. 129
Concerning Removal of Grease from Sewage....('41) R-195
Concrete Pipe, Flows Through....('46) R-271
Concrete Pipe, Flow of Water in....('46) R-273, ('47) R-271
Concrete Pipe, Water Flow in, Nomograph....('47) R-49
Concrete, Proportioning....('46) R-138
Concrete, Quantities of Materials (See also Proportioning Concrete) ....('45) R-134
Condition of Mains, Determining the....('46) R-37
Conductivity of Insulating Materials, Thermal....('47) R-64
Conical Piles, Contents of....('47) R-230
Connections, Eliminating Cross....('47) R-103
Conservation of Centrifugal Pumps....('44) R-63
Contemporary Chlorination Practices....('47) R-131
Contents of Conical Piles....('47) R-230
Contents of Horizontal Cylinders and Tanks.('45) R-261, ('47) R-264
Contents of Horizontal Tanks and Pipe....('45) R-270, ('47) R-264
Continuous Stability Indicator, Enslow....('46) R-169
Contrivances in a Small Treatment Plant....('46) R-209
Control, Automatic, of Centrifugal Pumps....('46) R-78
Control, Corrosion, In Potable Water Systems....('46) R-163
Control Flumes for Grit Chambers, Design of....('47) R-182
Control of Activated Sludge Bulking....('42) R-202, ('47) R-199
Control of Algae....('46) R-173, ('47) R-118
Control of Corrosion in Sludge Digester Parts....('46) R-242
Control of Insects by D.D.T....('47) R-225
Control of Micro-Organisms and Aquatic Vegetation....('44) R-127
Control of Odorous and Destructive Gases in Sewers and Treatment Plants....('47) R-185
Control of Sewage Chlorination....('47) R-243
Control of Sludge Bulking with Chlorine....('45) R-212, ('47) R-199
Control of Sludge Index by Chlorination....('47) R-199
Control of Solution Feed....('46) R-101
Control of Taste and Odors....('47) R-135
Control of Velocity in Grit Channels....('47) R-180
Control of Water Quality with Calgon....('45) R-151
Control of Weeds, Chemical....('47) R-121
Control, Sludge Digestion Temperature, by Live Steam...('46) R-229
Controlling Grit Chamber Velocities....('40) R-128
Conversion Factors....('47) R-262
Conversion Table, Metric....('46) R-54
Cooling Devices, Efficiency ....('47) Mag. 262
Converting Grains per Gal. to Lb. per Million....('47) R-129
Cooling Scheme, Underground Water....('43) R-109
Copper and Brass Pipe, Capacity and Pressure Loss Through ....('45) R-276
Copper and Health....('47) R-154
Copper Sulfate as an Aid to Sewer Maintenance and Sewage Treatment ....('42) R-197
Copper Sulphate for Killing Roots in Sewers....('44) R-246
Copper Sulfate in Algae Control....('47) R-118
Copper Sulfate, Usefulness and Application of....('45) R-119
Correct Rates of Flow for Testing Disc Meters....('46) R-117
Correction of Activated Sludge Bulking....('46) R-225
Correction of Corrosion of Sludge Digester Parts....('46) R-242
Correction of Water Hammer....('47) R-29
Correction of Water Waste Leakage....('44) R-105
Correctives, Water Hammer....('44) R-66, ('46) R-106
Corroded Service Line Cleaning with Compressed Air....('43) R-113
Corrosion—
Control in Water Systems....('46) R-163
Dissolved Oxygen Effect on....('45) R-149
Indicator ....('46) R-58
Measurement of Tuberculation....('47) R-155
Mechanism ....('47) R-149
Prevention ....('45) R-148
Prevention (Calgon Treatment)....('45) R-151
Protection, (Cathodic)..('43) R-83, ('45) R-67, ('46) R-235, R-242
Sludge Digestion Parts....('46) R-242
Stability Indicator....('46) R-169
Tuberculation Checked by Chloramine....('46) R-57
Tuberculation Measurement....('47) R-155
Corrosion Control in Potable Water Systems....('46) R-163
Corrosion of Sludge Digester Parts....('46) R-242
Corrosivity Indicator....('46) R-58
Cost of Leaks, Air, Steam, Water....('47) R-200
Cost of Mains, Estimating the....('42) R-104
Cost of Pumping Water, Determining....('45) R-101
Cost of Sludge Removal, Reducing....('47) R-227
Costs of Water at Stated Rates per 1000 Gallon....('47) R-126
Costs of Water Main Extensions....('47) Mag. 229
Costs, Pump Power: Method of Determination....('46) R-86
Court Decision on Water and Sewer Rents....('46) R-221
Critical Problem, Chlorine Solves a....('47) R-55
Cross Connections, Elimination of....('47) R-103
Cross, The Hardy, Method....('43) R-51
Current Flow and Heat Production....('45) R-50
Curve for Determining Flow in Components of Parallel Pipe Systems ....('47) R-39
Curves, Specific Speed....('46) R-80
Cutting Cast Iron Pipes....('44) R-75, R-111, ('47) R-91
Cutting Pipe, Speeded by Compressed Air....('44) R-111
Cylinder Contents, Horizontal and Vertical....('45) R-261, R-270, ('47) R-32
Cylinder Handling Carriage, Chlorine....('46) R-145
Cylinders, Contents of Horizontal....('45) R-261, ('47) R-264
Cylinders, Surface Areas of....('47) R-237
Clyindrical Tank, Capacities per Foot of Depth....('47) R-32

D

Damp Water Pipes, Painting....('44) R-154
Data, Engineering....('47) R-262
Data, Evaluation of Sewage Works....('47) R-253
D.D.T. for Insect Control....('47) R-235
Decimal Equivalents of Fractions....('46) R-212
Deep Well Centrifugal Pumps, Selecting....('46) R-87
Deep Well Pumps....('47) R-113
Deep Wells, Drilling and Developing....('46) R-21
Defense Measures For Sewage Works....('43) R-189
Degreasing Sewage....('43) R-211
Delivery Capacity and Pressure Drop Through Copper and Brass Pipe ....('45) R-276
Density Control of Activated Sludge....('47) R-197
Density to Volume Ratio in Sludge....('44) R-253
Depth Gauge Warns of Intake Troubles, Recording....('45) R-19
Depreciation, A-B-C of....('47) Mag. 237
Depreciation Accounting Practices, Municipal....('45) R-15
Design and Operation of Grease Interceptors....('45) R-233
Design Capacity of Supply Line Re-established by Chlorine....('47) R-53
Design, Installation, Operating Sludge Pumps....('46) R-219
Design of Air Distribution Systems for Activated Sludge Plants ....('44) R-206

REFERENCE AND DATA INDEX — 1941 through 1947

All subjects in this and previous issues are listed with the respective key,—('41), ('42), ('43), ('44), ('45), ('46), or ('47)

Design of Control Flumes for Grit Chambers..... ('47) R-182
Design of Grit Chambers..... ('41) R-144
Design of Sewers, Practices of..... ('44) Mag. 227
Destructive Gases in Sewers and Plants, Control of..... ('47) R-185
Detection of Waste Water in Sewer Flows..... ('47) R-252
Detector, Sludge Blanket..... ('41) R-230
Determination of—
Bacteria in Water..... ('46) R-171
Effective Dosage of Copper Sulfate in Algae Control.. ('47) R-118
Equivalent Pipes..... ('47) R-42
Flow in Parallel Pipe Systems..... ('47) R-39
Hydrogen Sulfide..... ('45) R-263
Per Cent Digestion..... ('46) R-256
Pumping Costs..... ('47) R-266
Residual Chlorine..... ('45) R-133, ('46) R-167
Sand in..... ('44) R-149
Settleable Solids..... ('46) R-208
Sludge Filtration Data..... ('47) R-239
Sludge Solids..... ('46) R-257
Sludge Solids by Centrifuge..... ('41) R-222
Sulfide ..... ('40) R-173
Suspended Solids..... ('45) R-262
Determination of Hydrogen Sulphide by Simple Method. . ('45) R-263
Determination of Power Costs..... ('46) R-86
Determination of Pumping Costs..... ('47) R-266
Determination of Sand in Well Water..... ('44) R-149
Determination of Settleable Sewage Solids by Weight.... ('46) R-208
Determining Cost of Pumping Water..... ('45) R-101
Determining Head, Capacity, Efficiency, Horsepower Chart..... ('47) R-267
Determining Per Cent Sludge Digestion, Chart for..... ('46) R-256
Determining the Condition of Mains..... ('46) R-37
Determining the Efficiency of Cooling Towers, Spray Ponds, etc. ..... ('47) Mag. 252
Determining Yardage on Reels or Drums..... ('47) R-212
Developing and Drilling, Deep Wells..... ('46) R-21
Development of Rock Wells..... ('45) R-51
Device for Feeding Lime Solution into Mains..... ('46) R-115
Dewatering Mains with Compressed Air..... ('46) R-48
Diagonal Pipe Runs..... ('46) R-68
Diagram for Velocity and Discharge in Clay Sewer Pipe.. ('42) R-193
Diagram, Pipe Flow..... ('47) R-269
Diesel Engine, Fume Trap for..... ('46) R-20
Diffused Air Activated Sludge Plant Operation..... ('44) R-211
Diffuser Plate, Cleaning..... ('44) R-222, ('47) R-201
Diffuser Plates, Method of Dry Cleaning..... ('46) R-238
Diffusers, Porous Air, Servicing..... ('46) R-230
Digester Parts, Corrosion of Sludge..... ('46) R-242
Digester Scum..... ('47) R-211
Digestion of Garbage with Sewage Sludge..... ('47) R-217
Digestion, Sludge, Chart for Determining Per Cent..... ('45) R-257, ('46) R-256
Digestion Temperature Control by Live Steam..... ('46) R-239
Digestion Unit Operation, Separate Sludge..... ('47) R-213
Direct Reading Arsenite-Ortho-Tolidine Test..... ('46) R-167
Discharge by Sprinkler Heads..... ('47) R-71
Discharge Diagram for Clay Sewer Pipe..... ('42) R-193
Discharge Measurements, Hydrant..... ('46) R-61
Discharge Table for Parshall Flume..... ('45) Mag. 207
Dissolved Oxygen Influence on Corrosion..... ('45) R-149
Dissolved Oxygen, Nomograph for Percent Saturation... ('41) R-290
Distribution—
Flow, (Hardy Cross Method)..... ('43) R-51
Loop Flows..... ('45) R-83
Operating with Cement Lining..... ('46) R-50
Repair of..... ('43) R-99
Storage ..... ('47) Mag. 233
System ..... ('47) R-35
Distribution in Loop Flows..... ('45) R-83
Distribution System, The..... ('47) R-35
Distribution Systems, Emergency Repair of..... ('43) R-99
Distribution Systems, uprating, by Cleaning and Cement Lining ..... ('46) R-51
Dosage Control In Sewage Chlorination..... ('47) R-243
Dosage of Copper Sulfate in Algae Control..... ('47) R-118
Dressing Rig, Vacuum Filter..... ('42) R-242
Drilling and Developing Deep Wells..... ('46) R-21
Drinking Water Standards, U. S. ..... ('46) Mag. 140
Drums or Reels, Yardage on..... ('47) R-212
Dry Chemical Feeders, Checking Chart for..... ('45) R-154
Dry Chemicals, Weights per Cu. Ft..... ('47) R-64
"Dry Cleaning" Air Diffuser Plates..... ('46) R-238

E

Earth Trenching..... ('46) R-27
Economic Aspects of Water Softening..... ('46) R-157
Economics of Cleaning Air Diffusion Media..... ('44) R-222
Effective Dosage of Copper Sulfate in Algae Control.... ('47) R-118
Effective Fire Streams..... ('47) R-88
Effect of Altitude on Pumps..... ('46) R-161
Effect of Carbonate and Bicarbonate Alkalinity on pH.. ('46) R-276
Efficiencies, Checking Centrifugal Pump..... ('44) R-59
Efficiencies, Pump, How to Compare..... ('45) R-52
Efficiency of Cooling Towers, Spray Ponds, etc...... ('47) Mag. 255
Efficiency, Horsepower, Head, Capacity..... ('47) R-267
Effluent Analyses, Sewage and..... ('42) R-250
Ejector and Washer, Grit..... ('46) R-234
Electrical Calculator, A Time Saver..... ('44) R-43
Electrical Control, Protection Against Moisture..... ('47) R-215
Electrical Data and Horsepower..... ('45) R-110
Electrical Motors, Protection Against Moisture..... ('47) R-215
Electrical Thawing..... ('46) R-40
Electric Heat Solves Problems at Pumping Station..... ('46) R-123
Electricity in the Plant, Practical..... ('47) R-59
Electronic Pipe Finding and Leaks Locating..... ('47) R-101
Elevated Storage.. ('44) R-91, ('45) R-64, ('46) R-73, ('47) R-67, R-70
Elevated Tank Maintenance..... ('45) R-64, ('47) R-67, R-70
Eliminating Cross Connections..... ('47) R-103
Eliminating Surge Troubles on Pump Discharge Lines.... ('44) R-66
Elimination of Check Valve Slam..... ('46) R-112
Elimination of Gas Hazards at Sewage Plants..... ('42) R-217
Emergency Method of Thawing Hydrants..... ('46) R-42
Emergency Repair of Distribution Systems..... ('43) R-99
Employee Profit Sharing Plan..... ('46) Mag. 143
Encrusted Pipe Lines and Vacuum Filters, Cleaning.... ('46) R-241
Encrusted Vacuum Filters, Acid Cleaning..... ('43) R-248
Engineering Data and Conversion Factors..... ('47) R-262
Engine, Gas, Maintenance and Operation..... ('47) R-205
Engine Operation on Sewage Sludge Gas..... ('45) R-225
Engine Performance, Gas..... ('45) R-229
Engines, Internal Combustion, Fume Trap for..... ('46) R-20
Engines, Sewage Gas..... ('46) R-259
Enslow Continuous Stability Indicator..... ('46) R-169
Entrances Losses, Hydraulic..... ('47) R-270
Equation of Pipes..... ('47) R-82
Equilibrium, Ionic, in Water..... ('45) R-156
Equipment and Tools for Sewage Works..... ('46) Mag. 150
Equipment, Maintenance of Water Works..... ('42) R-109
Equipping the Sewage Plant Laboratory..... ('47) R-255
Equivalent Pipe Charts..... ('45) R-83
Equivalent Pipes, Determination of..... ('47) R-42
Equivalents, Alkalinity..... ('45) R-282
Equivalents and Conversion Factors..... ('47) R-262
Equivalents, Decimals to Fractions of an Inch..... ('46) R-212
Equivalents, Heat and Power..... ('47) R-176
Equivalents of Ounces in Water and Mercury..... ('47) R-176
Estimating Flows from Low Pressure Fire Hydrants..... ('46) R-67
Estimating Length of Material in Rolls or Coils..... ('44) R-184
Estimating the Cost of Mains..... ('42) R-104
Estimation of Total Solids in Sludges by Centrifuging.... ('41) R-222
Evaluation of Pump Bids by Simple Method..... ('46) R-86
Evaluation of Sewage Works Data..... ('47) R-253
Examination of Water, Bacteriological Procedure for.... ('46) R-171
Examining 100 Ml. Portions of Water..... ('45) R-155
Exclusion of Oil Waste from Sewers..... ('46) R-195
Expansion Chart, of Pipe, Bar, Rail or Beam..... ('45) R-235
Experience in Diffused Air Activated Sludge Plant Operation ..... ('44) R-211
Experience in Mechanical Activated Sludge Plant Operation.... ..... ('45) R-203
Experience in Sewer Maintenance..... ('46) R-187
Experimental Observations on Digestion of Garbage with Sewage Solids..... ('47) R-217
Extension of Water Mains, Cost of..... ('47) Mag. 229

F

Factors and Data..... ('47) R-262
Factors in the Pollution of Sub-surface Water, Basic..... ('46) R-24
Feeder, Practical for Suspensions..... ('46) R-175
Feeders, Dry Chemical, Checking Chart for..... ('45) R-154
Feeding, Anhydrous Ammonia..... ('41) R-117
Feeding Device for Lime Solution..... ('46) R-115
Ferric Chloride..... ('44) R-241
Ferric Salts for Coagulation..... ('46) Mag. 147
Ferric Salts in Water and Sewage Treatment..... ('44) R-235
Fertility Values of Sewage Sludge..... ('43) R-264, ('46) R-249
Fertilizer
Sludge ..... ('45) R-259, ('47) R-229
Value ..... ('43) R-264, ('46) R-249
Fertilizer and Fertility Values of Sewage Sludge..... ('46) R-249
Field Maintenance of Large Meters..... ('42) R-128
Filter Bed Maintenance..... ('43) R-155
Filters—
Anthrafilt ..... ('45) R-145
Bed Maintenance ..... ('43) R-155
Bottoms, Porous ..... ('46) R-139
Cleaning Encrusted Vacuum..... ('46) R-241
Cleaning with Chlorine..... ('45) R-159
Cleaning with SO_2..... ('46) R-135
Mud-Balls in..... ('46) R-155
Plant Renovation and Rustproofing..... ('46) R-127
Sand Specifications..... ('46) Mag. 145
Sweep ..... ('43) R-155
Vacuum, Rig for..... ('42) R-242
Washing ..... ('44) R-151
Filter Sand Specifications..... ('46) Mag. 145
Filter Sweep ..... ('43) R-155
Filtration Data, Sludge..... ('47) R-239
Financing of Sewage Works..... ('47) R-161
Financing Sewage Works Operation..... ('44) R-164
Financing Sewerage..... ('41) R-129
Finding Pipe and Leaks, Electronic..... ('47) R-101

REFERENCE AND DATA INDEX — 1941 through 1947

All subjects in this and previous issues are listed with the respective key,—('41), ('42), ('43), ('44), ('45), ('46), or ('47)

Fire Flows Required for Towns by National Board of Fire Underwriters ('46) R-64
Fire Hydrant, Discharge Measurements ('46) R-61
Fire Hydrant Flow Gage ('45) R-50
Fire Hydrant Flows, Estimating ('46) R-67
Fire Protection, Water Supply in ('43) R-71
Fire Streams, Commercial Pipe Sizes for ('46) R-64
Fire Streams, Table of Effective ('47) R-88
Fittings and Pipes, Loss of Head in ('47) R-45
Fittings, Friction Chart for ('47) R-52
Fittings, Loss of Head Through ('42) R-69, ('47) R-45
Fittings, Screwed, Offset Chart for ('45) R-276
Fixture Water Requirements ('45) R-117
Flammability of Gas-Air Mixtures, Limits of ('46) R-201
Flocculated Samples, Collecting ('46) R-141
Floc Formation and Colloidal Silica ('44) Mag. 211
Flow—
- Capacity in Sewers ('46) R-266
- Circular Channel ('45) Mag. 201
- Circular Sewer ('46) R-270
- Friction, Measurement, Power ('44) R-17
- Gage for Sewers ('44) R-193
- Grid System ('40) R-44
- Grit Chambers ('40) R-138
- House Service ('47) R-145
- Hydrant ('46) R-61, R-67
- Hydrant, Fire ('45) R-50
- In Concrete Pipe ('46) R-271, R-273, ('47) R-271
- Loop ('45) R-83
- Measurement by Concentric Orifices ('46) Mag. 129
- Measurement by Orifice Method ('46) R-124
- Open Channel ('45) R-191, ('46) R-266
- Parallel Pipe Systems ('47) R-39
- Parshall Flume ('45) Mag. 207
- Pipe (Diagram) ('45) R-274, ('47) R-269
- Powergraph ('47) R-268
- Pulsating ('41) Mag. 289
- Rates for Fixtures ('45) R-117
- Rectangular Channel ('46) R-272
- Through Concrete Pipe ('46) R-271
- Through Pipe ('45) R-274

Flow Depth in Circular Channels or Conduits ('45) Mag. 201
Flow in Grid Systems ('40) R-44
Flow in House Service Pipes ('47) R-145
Flow Measurement in Grit Chambers ('40) R-138
Flow Measurements With Circular Orifice at End of Pipe ('46) R-39
Flow of Water in Concrete Pipe ('46) R-273, ('47) R-271
Flow of Water In House Service Pipes ('47) R-145
Flow Powergraph ('47) R-268
Flows Through Concrete Pipe ('46) R-271
Flume, Parshall, for Grit Chambers ('40) R-138
Flumes for Grit Chambers, Design ('47) R-182
Flushing of Small Mains, Compressed Air ('46) R-55
Flushing, Sewer ('46) R-192
Formation of Floc with Colloidal Silica ('44) Mag. 211
Formula for Flow in Open Channels, Manning's ('46) R-266
Free Flow Discharge Table for Parshall Measuring Flumes ('45) Mag. 207
Friction Chart for Valves and Fittings ('47) R-52
Friction Coefficients, Pipe Line ('42) R-59
Friction Loss—
- Fittings ('44) R-34
- Fittings and Pipes ('47) R-45
- Fittings and Valves ('42) R-69
- Hydraulic Entrance ('47) R-270
- Pipe ('47) R-46
- Valves ('42) R-69, ('44) R-34

Friction Losses in Mains ('46) R-37
Friction, Measurement, and Power, Flow ('44) R-17
Frost, Protecting Water Pipes from ('47) R-100
Fume Trap for Diesel and Other Internal Combustion Engines ('46) R-20
Functions of Numbers ('46) R-269
Fundamentals of the Activated Sludge Process ('45) R-197

G

Gage for Meter Change Gears ('47) R-111
Gage, Flow, Maximum, for Sewers ('46) R-193
Gage for Sewers, Maximum Flow ('44) R-193
Gage, Hydrant Flow ('45) R-50
Gages, Standard, for Sheets, Wire and Plates ('47) R-86
Gage Warns of Intake Troubles, Recording Depth ('45) R-18
Gallons in Water Supply Pipe (Nomograph) ('42) R-274
Garbage Digestion with Sludge ('47) R-217
Gas-Air Mixtures, Limits of Flammability ('46) R-201
Gas Engine Installations ('45) R-228
Gas Engine Maintenance and Operation ('47) R-205
Gas Engine Operation on Sewage Sludge Gas ('45) R-225
Gas Engine Performance ('45) R-229
Gases in Sewers and Plants, Control of ('47) R-185
Gas Hazards ('46) R-199
Gas Hazards at Sewage Plants ('42) R-217
Gas Scrubbing ('46) R-261
Gas, Sewage, Engines ('46) R-259
Gasoline, Use in Dry Cleaning Diffuser Plates ('43) R-246
Gate Valve Care and Maintenance ('47) R-54
Gear Gage, Change, for Meter ('47) R-111
Generation of Power, with Sewage Gas Engines ('46) R-249
Grains per Gal. to Lb. per Million ('47) R-120
Grease Interceptors, Design & Operation of ('45) R-233
Grease Removal from Sewage ('41) R-196
Grid System Flow ('40) R-44
Grinding Sewage Screenings ('43) R-194
Grit Chambers ('41) R-152
Grit Chamber Design ('41) R-144
Grit Chambers, Design of Flumes ('47) R-182
Grit Chamber Velocities, Controlling ('40) R-138
Grit Channel, Velocity Control ('47) R-180
Grit Collection and Washing ('41) R-156
Grit Removal ('41) R-144
Grit Washer and Ejector, Pnuematic ('46) R-224
Ground Water Infiltration Studies ('47) R-169
Guides and Checks on Water Works Operation ('46) R-15

H

Hammer, Water ('47) R-29
Hammer, Water, Checking ('46) R-113
Hammer, Water, Correctives ('46) R-106
Handling and Use of Chlorine ('47) Mag. 253
Handling Anhydrous Ammonia ('41) R-117
Handling Chlorine, Practical Aspects of ('47) R-127
Handling Pipe ('47) R-54
Handling Sewage Sludge Problems ('45) R-246
Hardness and Iron Removal ('46) R-183
Hardness, Water Removal ('46) R-157
Hard-Spot Breaker, Mud-Ball and ('46) R-155
Hardy Cross Method ('43) R-51
Hazards at Sewage Plants, Gas ('42) R-217
Hazards, Gas ('46) R-199
Head, Capacity, Efficiency, Horsepower ('47) R-267
Head Losses, Hydaulic Entrance ('47) R-270
Head Loss in Pipe Chart ('44) R-28, ('46) R-268
Head Loss in Pipes and Fittings ('47) R-45
Head Loss, Through Valves & Fittings ('47) R-52
Heads and Flows in Pipe Systems (Hardy Cross Method) ('43) R-51
Heads of Water to Pressure in Psi ('46) R-79
Health and Copper ('47) R-154
Heat and Power Equivalents ('47) R-170
Heat, Electric, Solves Problems at Pumping Station ('46) R-123
Heating Sludge Digestion Tanks ('45) R-215
Heat Production and Current Flow ('45) R-89
Horizontal Cylinders and Tanks, Contents of ('45) R-261, ('47) R-264
Horsepower and Electrical Data ('45) R-110
Horsepower from Watt-Hour Meters, Computing ('46) R-114
Horsepower, Head, Capacity, Efficency ('47) R-267
Hourly Load Variations in Relation to Sewage Treatment Plant Operation ('46) R-207
House Service Pipes, Flow of Water in ('47) R-145
How to Bend Pipes ('46) R-77
How to Compare Pump Efficiencies ('45) R-82
How To Use D.D.T. for Insect Control ('47) R-226
Humidity Chart ('40) R-200
Hydrant Discharge Measurements ('46) R-61
Hydrant Flow Gage ('45) R-50
Hydrant Maintenance ('47) R-57
Hydrants, Low Pressure Fire, Estimating Flows from ('46) R-67
Hydrants, Method of Thawing ('46) R-62
Hydraulic Entrance Losses ('47) R-270
Hydraulic Power-Lift Chart ('42) R-270
Hydraulics for the Practical Water Works Man (Part IX) ('47) Mag. 245
Hydraulics, Practical ('45) R-61
Hydrogen Sulfide Determination by Simple Method ('45) R-201
Hypo-chlorinator, Inexpensive ('47) R-246

I

I-Beam Loadings ('45) R-221
Ice, Chlorine, Solving Problem ('47) R-129
Ice, Protecting Reservoir Against ('42) R-113
Importance of Testing Disc Meters at the Correct Rates of Flow ('46) R-117
Improved Method for Rating Wells ('45) R-47
Improved Method of Making Wet Taps ('46) R-69
Improved Method of Velocity Control in Grit Channels ('47) R-180
Improved Residual Chlorine Test ('45) R-133
Improving the Operation of a Small Treatment Plant ('46) R-209
Incineration of Sludge ('47) R-225
Inclined Diagonal Pipe Runs—Calculating Pipe Lengths ('46) R-61
Increasing Well Production ('46) R-73
Incrustation in Lime Solution Lines, How to Retard ('43) R-223
Incrusted Wells, Treating ('46) R-73
Index of Corrosion, Tuberculation Measurement as ('47) R-186

REFERENCE AND DATA INDEX — 1941 through 1947

All subjects in this and previous issues are listed with the respective key,—('41), ('42), ('43), ('44), ('45), ('46), or ('47)

Index of Products, Classified.....('47) R-2
Index Test, Sludge.....('44) Mag. 222
Indicator, Corrosivity.....('46) R-58
Indicator, Stability, Enslow Continuous.....('46) R-169
Industrial Waste—
Service Charges.....('44) R-166
Soapy Waters, Treatment of.....('46) R-253
Inexpensive Hypo-clorinator.....('47) R-246
Infiltration Studies.....('47) R-169
Influence of Dissolved Oxygen on Corrosion Losses.....('45) R-149
Information on Water and Sewage Works Problems.....('46) R-13
Inhibited Muriatic Acid for Cleaning Encrusted Lines and Vacuum Filters.....('46) R-241
Inhibitors, Use of, in Cleaning Pipe.....('46) R-161
Inlet and Manhole Traps for Sewer Odors.....('47) R-172
Insect Control with D.D.T.....('47) R-235
Instructive Wall Panel for Treatment Plants.....('47) R-228
Insulating Materials, Thermal Conductivity of.....('47) R-64
Installation, Operation, Design of Sludge Pumps.....('46) R-219
Intake Troubles, Recording Depth Gauge Warns of.....('45) R-50
Interceptors, Grease, Design and Operation.....('45) R-233
Internal Combustion Engines, Fume Trap for.....('46) R-20
Interpretation of Chemical Analyses of Water.....('46) R-148
Interpretation of Sewage Analyses.....('42) R-250
Ionic Equilibrium In Water.....('45) R-156
Iron and Hardness Removal.....('46) R-153
Iron Removal—Small Systems.....('45) R-141

J

Joint Administration and Collection of Water and Sewer Accounts.....('46) R-177
Joint Caulking, Pnuematic.....('47) R-89
Jointing, Proper Sewer.....('47) R-171
Journals on Water and Sewage Works.....('46) R-13

K

Keeping Filters Clean With Chlorine.....('45) R-159
Keeping Lime Solution Lines Clean.....('45) R-241
Killing Roots in Sewers with Copper Sulphate.....('47) R-245
Kinks and Gadgets in a Sewage Plant.....('46) R-209
Kinks, Some Sewerage Operating.....('45) R-181
Kutler's Formula, Approximate.....('44) R-168

L

Laboratory Equipment for Sewage Plants.....('47) R-255
Laboratory in Small Water Purification Plants.....('47) Mag. 249
Land Measure.....('46) R-30
Lagooning, Sludge.....('47) R-231
Lands, Reforestation of Water Works.....('47) R-13
Large Meter Maintenance in Field.....('42) R-128
Leakage Correction and Water Waste Surveys.....('44) R-105
Leakage Studies.....('46) Mag. 137
Leak Costs.....('45) R-108
Leak Costs, Air Steam, Water.....('47) R-200
Leak Locating, Pipe Finding, Electronic.....('47) R-101
Legal Responsibilities of Water Operators.....('46) R-18
Lengths of Diagonal Pipe Runs.....('46) R-68
Length of Material in Rolls or Coils.....('44) R-184
Levelling and Aligning Method.....('45) R-46
Lime and Lime Slaking.....('45) R-139
Lime Solution, Device for Feeding.....('46) R-115
Lime Solution Lines, How to Clean.....('45) R-241
Limits of Flammability of Gas-Air Mixtures.....('46) R-201
Line Current Calculator.....('45) Mag. 300
Lines, Service, Blowing Out.....('47) R-99
Lining Cast Iron Mains In Place With Cement Mortar...('45) R-96
Liquid Chlorine.....('46) R-142
List of Books on Water and Sewage Works.....('46) R-13
Literature on Water and Sewage Works Problems.....('46) R-13
Live Steam for Sludge Digestion Temperature Control....('46) R-239
Loading for I-Beams, Safe.....('45) R-281
Loading for Wooden Beams, Safe.....('45) R-280
Load Variations in Sewage Plants.....('46) R-207
Locating Lost Sewers and Manholes.....('46) Mag. 149
Log for Small Sewage Plant.....('46) R-214
Logs for Small Water Plants, Operating.....('45) R-152
Loop Flow Distribution Charts.....('45) R-82
Los Angeles, Elimination of Cross Connections in.....('47) R-103
Losses, Hydraulic Entrance.....('43) R-279
Losses in "C" Value in Mains.....('46) R-37
Loss of Head (See Friction Loss)
Loss of Head, Hydraulic Entrance.....('47) R-270
Loss of Head in Pipe, Chart.....('46) R-268, ('47) R-46
Loss of Head in Pipes and Fittings.....('47) R-45
Loss of Head Through Valves and Fittings.....('47) R-53
Lost Sewers and Manholes, Locating.....('46) Mag. 149
Low Pressure Fire Hydrants, Estimating Flows from....('46) R-67
Lubrication Check Sheet.....('46) R-213

M

Magazines on Water and Sewage Works.....('46) R-13
Main Cleaning With Compressed Air.....('47) R-81
Main-Line Metering of Water, Sewage and Sludge.....('45) R-34
Main Line Meters, Selection of.....('44) R-45
Mains—
Branches.....('47) R-38
Caulking Joints of.....('44) R-109
Cement Lining.....('45) R-96, ('46) R-50
Cleaning.....('45) Mag. 192, ('47) R-78
Condition of ("C" Value).....('46) R-37
Cost of, Estimating.....('42) R-104
Cross Connections.....('47) R-103
Cutting.....('44) R-75, R-111, ('47) R-91
Dewatering.....('46) R-48
Extensions.....('47) Mag. 229
Flushing Small.....('46) R-55
Tapping.....('46) R-48
Thawing Small.....('46) R-40
Maintenance—
Gas Engine.....('47) R-205
Elevated Tanks.....('42) R-89, ('47) R-67, R-70
Filter Bed.....('43) R-155
Gate Valve.....('47) R-84
Hydrant.....('40) R-96, ('47) R-87
Meters, Water (Large).....('42) R-121, R-128, ('45) R-253
Pumping Stations.....('44) R-199
Pumps, Deep Well.....('47) R-113
Sewage Pumping Stations.....('47) R-177
Sewer.....('46) R-180, R-187, ('47) Mag. 249, R-166
Standpipes.....('42) R-89
Tanks.....('43) R-80, ('47) R-67, R-70
Valve.....('40) R-96, ('45) R-105
Water Works Equipment.....('42) R-109
Well Capacity.....('47) R-109
Wells.....('47) R-107
Maintenance of Elevated Tanks.....('47) R-67
Maintenance of Large Meters in the Field.....('42) R-128
Maintenance of Sewage Pumping Stations.....('47) R-177
Maintenance of Tanks and Standpipes.....('42) R-89
Maintenance of Valves and Hydrants.....('40) R-96
Maintenance of Water Well Capacity.....('47) R-109
Maintenance of Waterworks Equipment.....('42) R-109
Making Pipe Bushings from Standard Pipe.....('47) R-69
Making Wet Taps, Method of.....('46) R-48
Management, Problems in Municipal Waterworks.....('43) R-21
Manganese Removal.....('44) R-147
Manganese Removal by Breakpoint Chlorination.....('47) R-159
Manhole Odors, Sewer, Traps for.....('47) R-172
Manholes and Sewers, Locating.....('46) Mag. 149
Manning's Formula, for Open Channel Flow.....('46) R-266
Manning's Formula Nomograph.....('45) R-278
Manual of Water Sanitation Practice.....('43) R-128
Manuals on Water and Sewage Works.....('46) R-13
Manufacturers of Water and Sewage Works Products....('47) R-2
Materials, Pipe.....('46) R-33
Materials, Thermal Conductivity of Insulating.....('47) R-64
Materials, Weights of.....('46) R-170
Maximum Flow Gage for Sewers.....('46) R-193
Measurement, and Power, Flow, Friction.....('44) R-17
Measurement, Flow, with Circular Orifice.....('46) R-39
Measurement of Flow by Concentric Orifices.....('46) Mag. 129
Measurement of Flow in Open Channels.....('45) R-191
Measurement of Tuberculation As Index of Corrosion.....('47) R-155
Measurements, Hydrant Discharge.....('46) R-61
Measures and Weights.....('47) R-264
Measures For Defense of Sewage Works.....('43) R-188
Measures of Land.....('44) R-55
Measuring Flows, By the Orifice Method.....('46) R-124
Measuring Pulsating Flow Accurately.....('41) Mag. 289
Mechanical Activated Sludge Plant Operation, Experience in.....('45) R-203
Mechanism of Corrosion of Water Pipes, The.....('47) R-149
Mechanical Sewer Cleaning.....('47) Mag. 249
Mercury and Water, Equivalents of Ounces in.....('47) R-176
Media for Air Diffusion, Economics of Cleaning.....('44) R-222
Metal Protection, Cathodic.....('43) R-83
Metals, Preparation for Painting.....('47) R-72
Meter—
Casings, Cleaning.....('46) R-125
Change Gear Gage.....('47) R-111
Main Line.....('45) R-34

REFERENCE AND DATA INDEX — 1941 through 1947

All subjects in this and previous issues are listed with the respective key,—('41), ('42), ('43), ('44), ('45), ('46), or ('47)

Maintenance (Large)....('42) R-128
Maintenance Practice....('42) R-121
Methods ....('47) R-75
Propeller Type....('45) R-37
Renovating ....('47) R-76
Repair Shop....('46) R-121
Selection of....('46) R-119
Shop Practice....('40) Mag. 165
Testing ....('46) R-116, R-117
Watt-Hour ....('46) R-114
Meter Casing Cleaning, by Sand Blasting....('46) R-124
Metering and Meter Shop Practice....('40) Mag. 165
Metering of Water, Sewage and Sludge, Main Line....('45) R-34
Metering, Practical Methods of Procedure....('47) R-75
Meters, Large, Maintenance in Field....('42) R-128
Method for Cutting Cast-Iron Pipe....('47) R-91
Method for H_2S Determination....('45) R-263
Method for Rapid Determination of Sludge Solids....('46) R-257
Method for Rating and Sampling Wells....('45) R-47
Method of Aligning and Levelling....('45) R-46
Method of Making Wet Taps....('46) R-48
Mehod of Thawing Hydrants....('46) R-42
Method of Velocity Control in Grit Channels....('47) R-180
Methods of Procedure for Metering....('47) R-75
Metric Conversion Table....('46) R-54
Micro-organisms and Aquatic Vegetation, Control of....('44) R-127
Modern Financing of Sewage Works....('47) R-161
Modern Practices in Municipal Water Softening....('47) R-141
Moisture, Protection of Motors and Controls....('47) R-215
Motors and Controls, Protection Against Moisture....('47) R-215
Mud-Ball and Hard-Spot Breaker....('46) R-155
Mud Hog, The....('45) R-116
Municipal Depreciation Accounting Practices....('45) R-15
Municipal Utility Profit Sharing Plan....('46) Mag. 143
Municipal Water Softening....('47) R-141
Municipal Water Works Lands, Reforestation of....('47) R-13
Municipal Waterworks Management, Problems in....('43) R-21
Muriatic Acid, Inhibited, for Removing Encrustations...('46) R-241

N

National Board of Fire Underwriters Fire Flow Requirements....('46) R-64
Natural Waters, Characteristics of....('46) R-116
New Method for Cutting Cast-Iron Pipe....('47) R-91
Nomograph for Determination of Sludge Filtration....('47) R-239
Nomograph for Percent Saturation of Dissolved Oxygen..('41) R-290
Nomograph for Solving Manning's Formula....('45) R-278
Nomograph for Water Pipe Flow....('45) R-274
Nomographic Chart for Flow in Pipes....('45) R-40
Nozzle Replacement on Trickling Filters....('46) R-214
Number of Taps That Can be Taken from Pipe of Various Sizes....('45) R-274
Numbers, Roots and Powers of (Nomograph)....('42) R-278

O

Odor Control with Activated Carbon....('47) R-135
Odor Removal—
Activated Carbon....('47) R-135
Algae Control for....('44) R-127, ('46) R-173
Micro-organism Control....('44) R-127
Odors and Gases in Sewers and Plants, Control of....('47) R-185
Odor Traps for Sewer Manholes and Inlets....('47) R-172
Offset Chart for Screwed Fittings....('45) R-276
Oil Waste Exclusion from Sewers....('46) R-195
Open Channel Flow Measurement by Parshall Flume....('45) R-191
Open Channel Flow (Nomograph)....('46) R-266
Operating and Experimental Observations on Digestion of Garbage with Sewage Solids....('47) R-217
Operating Engines on Sewage Sludge Gas....('45) R-225
Operating Fundamentals of the Activated Sludge Process.('45) R-197
Operating Kinks, Sewerage....('45) R-181
Operating Log for a Small Sewage Plant....('46) R-214
Operating Logs for Small Water Plants....('45) R-152
Operating Reports for Sewage Plants....('47) R-247
Operation and Maintenance of Small Pumping Stations...('44) R-199
Operation, Automatic, of Centrifugal Pumps....('46) R-78
Operation Charts in Sewage Works....('47) R-249
Operation, Design, Installation of Sludge Pumps....('46) R-219
Operation of Activated Sludge Plants....('44) R-211, ('47) R-191
Operation of a Small Treatment Plant....('46) R-209
Operation of Grease Interceptors....('45) R-233
Operation of Separate Sludge Digestion Units....('47) R-213
Operation of Sewage Treatment Plants....('45) R-187
Operation, Waterworks, Guides and Checks on....('46) R-15
Operator's Standpoint, Scum Problem from....('47) R-211
Operator's, Water, Legal Responsibility of....('46) R-18
Orifice, Circular for Flow Measurement....('46) R-39
Orifice Method, Measuring Flows by....('46) R-124
Orifices, Concentric....('46) Mag. 129
Ortho-Tolidine-Arsenite Test, Direct Reading....('46) R-167
Ortho-Tolidine-Arsenite (OTA) Test for Residual Chlorine.('45) R-123
Ounces of Water and Mercury, Equivalents....('47) R-176
Oxidants and Reductants in Sewage Plant Effluents and Streams....('45) R-211
Oxygen, Dissolved, Influence on Corrosion....('45) R-149

P

Jacking Pointers....('44) R-204
Painting, and Protecting Steel Water Tanks....('45) R-64
Painting Damp Water Pipes....('44) R-154
Painting, Preparation of Metals for....('47) R-72
Palmer Filter Sweep....('43) R-155
Panel, Wall, for Treatment Plants....('47) R-228
Parallel Pipe Systems, Determining Flow in....('47) R-39
Parshall Flumes—
Discharge Table....('45) Mag. 207
For Open Channel Flow Measurement....('45) R-191
In Grit Chambers....('40) R-130
Peculiarities, Centrifugal Pump....('46) R-75
Per Cent Saturation of Dissolved Oxygen....('41) R-290
Per Cent Sludge Digestion, Chart for Determining....('46) R-256
Performance, Gas Engine....('45) R-229
pH, Alkalinity and CO_2 Relations....('46) R-274
pH Conversion Chart....('46) R-274
pH, Effect of Alkalinity on....('46) R-275
pH Zones of Import in Water Supply and Sewage Treatment Practice....('43) R-285
Piles, Conical, Contents of....('47) R-230
Pipe—
And Fittings, Loss of Head in....('47) R-45
Bushings ....('47) R-69
Chart ....('46) Mag. 160
Cleaning Encrusted ....('46) R-161, R-241
Columns, Safe....('47) R-170
Concrete, Flow in....('46) R-271, R-273, ('47) R-49, R-271
Corrosion Mechanism....('47) R-149
Cutting....('44) R-75, R-111, ('47) R-91
Diagonal Runs of....('43) R-65
Equation of....('47) R-82
Equivalent ....('45) R-53
Equivalent, Determination of....('47) R-42
Finding, Electronic....('47) R-101
Flow Diagram....('47) R-269
Flow in (See Flow)
Friction Loss....('47) R-45
Handling ....('47) R-54
How to Bend....('46) R-77
Joints, Caulking....('47) R-89
Line, Carrying Capacity ....('47) R-263
Line, Friction Coefficients ....('42) R-59
Materials ....('46) R-33
Painting Damp....('44) R-154
Parallel Systems, Flow in....('47) R-39
Protecting from Frost....('47) R-100
Sewer, Discharge of....('46) R-266
Sweating, To Stop....('45) R-131
System (Hardy Cross Method)....('43) R-51
Velocity in....('46) R-276
Pipe Finding and Leak Locating, Electronic....('47) R-101
Pipe Flow Diagram....('47) R-269
Pipe Handling Simplified....('47) R-54
Pipe Line Friction Coefficients....('42) R-59
Pipe Materials....('46) R-33
Piping within Buildings, Regulating Water....('45) R-19
Pitometer Surveys....('46) Mag. 137
Plan, Employee Profit Sharing....('46) Mag. 143
Plan for Sewage Works Operation Financing, Revenue...('44) R-164
Plant Operation, Activated Sludge....('47) R-191
Plant Operation, Sewage Treatment....('45) R-187
Plants, Filter, Renovating and Rustproofing....('46) R-137
Plant, Practical Electricity for....('47) R-59
Plant Records and Operating Reports....('47) R-247
Plant, Small Sewage, Operating Log....('46) R-214
Plants, Operating Logs for Small Water....('45) R-152
Plate, Porous Filter Bottoms....('46) R-139
Plates, Air Diffuser, Purging with Chlorine....('44) R-221
Plates, Standard Gages for....('47) R-86
Plus Values of Sewage Sludge, Fertility....('43) R-264
Pneumatic Caulking of Pipe Joints....('47) R-89
Pneumatic Grit Washer and Ejector....('46) R-234
Pollution of Sub-surface Water, Basic Factors in....('46) R-24
Porous Air Diffuser Servicing....('46) R-230
Porous Plate Filter Bottoms....('46) R-139
Potable Water Systems, Corrosion Control in....('46) R-163
Pounding, Pump, Corrected by Air Sniffer....('46) R-84
Pounds per Million to Grains per Gal....('47) R-120
Power and Heat Equivalents....('47) R-176
Power Costs, Determination of....('46) R-86
Power Costs, Evaluating Pump Bids....('46) R-86
Power Crane Truck....('47) R-54
Power, Flow, Friction, Measurement, and....('44) R-17
Power Generation with Sewage Gas Engines....('46) R-259

REFERENCE AND DATA INDEX — 1941 through 1947

All subjects in this and previous issues are listed with the respective key,—('41), ('42), ('43), ('44), ('45), ('46), or ('47)

Powergraph, Flow ('47) R-268
Power-Lift Chart, Hydraulic ('42) R-270
Powers and Roots of Numbers (Nomograph) ('42) R-278
Practical Aspects of Handling Chlorine ('47) R-127
Practical Aspects of Porous Plate Filter Bottoms ('46) R-139
Practical Carbon Feeder ('46) R-175
Practical Electricity in the Plant ('47) R-59
Practical Hydraulics ('45) R-43, ('47) Mag. 245
Practical Methods of Metering ('47) R-75
Practice and Principles in Testing Water Meters ('46) R-116
Practice, Sanitation, Manual of Water ('43) R-128
Practices, Contemporary Chlorination ('47) R-131
Practices in Municipal Depreciation Accounting ('45) R-15
Practices in Municipal Water Softening ('47) R-141
Practices, Sewer Design ('44) Mag. 227
Practice, Trenching ('46) R-27
Practice, Water Meter Maintenance ('42) R-121
Pre-determining Effective Dosage of Copper Sulfate in Algae Control ('47) R-118
Preparation of Metals for Painting ('47) R-72
Preservation of Sewage Samples ('41) Mag. 285
Pressure Drop Through Brass and Copper Pipe ('45) R-276
Pressure in Psi. for Different Heads of Water (See also Water Pressure) ('46) R-79
Pressure, Water—Head to Pounds ('45) R-283
Preventing Corrosion by Water Treatment ('45) R-148
Principles and Practice in Testing Water Meters ('46) R-116
Principles of Power Generation with Sewage Gas Engines. ('46) R-259
Prob'em, Chlorine Solves Critical ('47) R-55
Problem, Scum ('47) R-211
Problems in Handling Sewage Sludge ('45) R-245
Problem of Chlorine Ice ('47) R-129
Problems in Municipal Waterworks Management ('43) R-21
Procedure, Practical, for Metering ('47) R-75
Procedure, Simplified Bacteriological for Water Examination ('46) R-171
Process, Activated Sludge ('45) R-197, ('47) R-191
Processes and Results, Sewage Treatment ('44) R-175
Processes, Sewage Treatment (In Brief) ('41) R-173
Production, Well, Increasing ('46) R-23
Products, Classified Index of ('47) R-2
Profit Sharing Plan, Employee ('46) Mag. 143
Propeller-Type Meters ('45) R-37
Proper Sewer Jointing ('47) R-171
Properties of Chlorine ('46) R-142
Proportional Feeder ('47) R-246
Proportioning Concrete ('46) R-138
Protecting A Reservoir Against Ice ('42) R-118
Protecting Steel Water Tanks ('45) R-64, ('47) R-67
Protecting Water Pipes from Frost ('47) R-100
Protection, Cathodic ('43) R-83
Protection, Cathodic, of Mechanical Sewage Filters ('46) R-235
Protection, Cathodic, of Steel Surfaces in Contact with Water ('45) R-67
Protection, Fire, Water Supply in ('43) R-71
Protection of Motors and Controls Against Moisture ('47) R-215
Public Relations in Water and Sewage Works ('47) R-17
Pumps—
Bids, Evaluating ('46) R-86
Capacity of Reciprocating ('42) R-274
Cavitation in ('46) Mag. 125
Centrifugal ('46) R-75, ('47) R-21
Centrifugal, Automatic Operation of ('46) R-78
Centrifugal, Conservation of ('44) R-63
Deep Well ('47) R-113
Deep Well, Selection of ('46) R-87
Discharge Line Surge ('44) R-66
Efficiencies ('45) R-52
Maintenance ('44) R-63
Pounding ('46) R-84
Sewage, Air Release for ('45) R-256
Specific Speed Curves for ('46) R-80
Suction Bells ('46) R-83
Terminology ('44) R-62
Trouble Check Sheet ('46) R-85
Pumping Costs, Chart for Determination of ('47) R-266
Pumping Costs of Water, Determining ('45) R-101
Pumping Problem, Air Release Solves ('45) R-256
Pumping, Sewage and Sludge ('47) R-173
Pumping Sludge ('46) R-219
Pumping Station Operation and Maintenance ('44) R-199
Pumping Station Problem Solved by Electric Heat ('46) R-123
Pumping Stations, Maintenance of Sewage ('47) R-177
Pumping Terminology ('44) R-62
Pump Pounding Corrected by Simple Air Sniffer ('46) R-84
Pump Trouble Check Sheet ('46) R-85
Purchase and Maintenance of Deep Well Pumps ('47) R-113
Purging Air Diffuser Plates with Chlorine ('44) R-221

Q

Quality of Water Control with Calgon ('45) R-151
Quantities of Materials for Concrete (see also Proportioning Concrete) ('45) R-134
Quick Way to Estimate Length of Material in Any Roll or Coil ('44) R-184

R

Recovering Well Capacity with Chlorine ('47) R-112
Rectangular Weirs, Capacity of ('47) R-273
Rehabilitation and Cleaning of Wells ('47) R-107
Renovating Water Meters ('47) R-76
Rapid Emergency Method of Thawing Hydrants ('46) R-42
Rapid Method for Determining Sludge Solids ('46) R-257
Rate of Flow, Correct, for Testing Disc Meters ('46) R-117
Rate of Flow in Circular Sewers ('46) R-270
Rate of Flow in Rectangular Channels ('46) R-272
Rates of Flow for Various Uses and Fixtures ('47) R-92
Rating and Sampling Wells by an Improved Method ('45) R-47
Ratio of Sludge Density to Volume ('44) R-252
Reciprocating Pumps, Capacity of (Nomograph) ('42) R-274
Recording Depth Gauge Warns of Intake Troubles ('45) R-18
Records, Sewage Plant (Logs) ('46) R-214, ('47) R-247
Rectangular Channel Flow ('46) R-272
Reducing Cost of Sludge Removal ('47) R-227
Reducing Gas Hazards ('46) R-199
Reductants and Oxidants in Sewage Plant Effluents and Streams ('45) R-211
Reels or Drums, Yardage on ('47) R-212
Reforestation of Municipal Water Works Lands ('47) R-13
Regulating Water Piping Within Buildings ('45) R-19
Relation of Load Variation to Sewage Plant Operation ('46) R-207
Relationships Between Current Flows and Heat Production ('45) R-50
Relations, Public ('47) R-17
Relative Carrying Capacities of Pipe Lines of Equal Smoothness ('47) R-263
Relative Sizes of Branches and Water Mains ('47) R-38
Relative Values of Alkalinity, pH and Co_2 ('46) R-274
Removal of Grease from Sewage ('41) R-195
Removal of Grit ('41) R-144
Removal of H_2S from Gas ('46) R-261
Removal of Iron and Hardness ('46) R-153
Removal of Iron in Small Systems ('45) R-141
Removal of Manganese ('44) R-147, ('47) R-159
Removal of Manganese by Breakpoint Chlorination ('47) R-159
Removal of Sludge, Reducing Cost of ('47) R-227
Removal, Sand, from Well Water ('42) R-114
Renovation and Rustproofing Applied to Filter Plants ('46) R-127
Rents, Water Service and Sewer ('46) R-221
Repainting Steel Water Tanks ('47) R-70
Repair of Distribution System, Emergency ('43) R-99
Repair Shop, Small Meter ('46) R-121
Replacement of Trickling Filter Nozzles ('46) R-214
Reports for Sewage Plants ('47) R-247
Requirements, Water ('47) R-92
Reservoir, Protecting, Against Ice ('42) R-118
Reservoir Silting ('41) Mag. 267
Residual Chlorine, Ortho-Tolidine-Arsenite Test for ('45) R-133
Residual Chlorine Test, Direct Reading OTA ('46) R-167
Responsibilities of Water Operators, Legal ('46) R-18
Revenue Plan for Sewage Works Financing ('44) R-164
Revolving Watt-Hour Meters, Computing Horsepower from ('46) R-114
Rig, Dressing, Vacuum Filter ('42) R-242
Right Meter, Selecting the ('46) R-119
Rock Trenching ('46) R-27
Rock Well Development ('45) R-51
Rolls or Coils, Length of Material in ('44) R-184
Root Removal with Copper Sulfate ('42) R-197, ('47) R-245
Roots and Powers of Numbers (Nomograph) ('42) R-278
Roots in Sewers, Killing ('42) R-197, ('47) R-245
Rubber Beach Balls, for Sewer Cleaning ('43) R-182
Rustproofing in Filter Plants ('46) R-127

S

Safe Columns from Standard Pipes ('47) R-170
Safe Loading for I-Beams ('45) R-281
Safe Loading for Wooden Beams ('45) R-280
Safety Cylinder Handling Carriage ('46) R-145
Sampling and Rating Wells ('45) R-47
Sand Blasting for Cleaning Meter Casings ('46) R-124
Sand in Well Water, Determination of ('44) R-149
Sand Removal from Well Water ('42) R-114
Sand Specifications, Filter ('46) Mag. 145
Sanitation Practice, Manual of Water ('43) R-128
Scobey Formula ('46) R-273
Scope of Pitometer Surveys in Waste Water and Leakage Studies ('46) Mag. 137
Screenings, Trituration of Sewage ('43) R-194
Screwed Fittings, Offset Chart for ('45) R-276
Scum Problem from the Operator's Standpoint, The ('47) R-211
Selecting Deep Well Centrifugal Pumps ('46) R-87
Selecting the Right Meter ('46) R-119
Selection of Centrifugal Pumps ('47) R-21
Selection of Main Line Meters ('44) R-45
Self-Cleaning Strainers, for Sand Removal ('42) R-114
Separate Sludge Digestion Unit Operation ('47) R-213
Service and Maintenance of Sewers ('47) R-166
Service Charges for Industrial Waste, Special Sewer ('44) R-166
Service Lines, Blowing Out ('47) R-99
Service Lines, Electrical Thawing of ('46) R-40

REFERENCE AND DATA INDEX — 1941 through 1947

All subjects in this and previous issues are listed with the respective key,—('41), ('42), ('43), ('44), ('45), ('46), or ('47)

Service Pipes, Flow in House ('47) R-145
Service Shooting ('43) R-113
Service, Standards for Water ('45) R-111
Servicing Porous Air Diffusers ('46) R-230
Settleable Sewage Solids, Determination of, by weight ('46) R-208
Sewage—
Analyses ('42) R-250
Chlorination, Control of ('47) R-243
Gas (see Sludge Gas)
Grease Removal ('41) R-195, ('45) R-233
Grit Chambers Flumes ('47) R-182
Load Variation ('46) R-207
Plant Effluents ('45) R-211
Plant Equipment Protection ('46) R-235
Plant Gas Hazards ('42) R-217
Plant Laboratory ('47) R-255
Plant Operating Log ('46) R-214
Plant Records (Reports) ('46) R-214, ('47) R-247
Pumping ('45) R-249, R-256
Pumping Stations ('47) R-177
Screenings ('43) R-194
Settleable Solids ('46) R-208
Slide Rule for Operators ('44) R-184
Sludge (see Sludge)
Sludge Digestion with Garbage ('47) R-217
Works, Books on ('46) R-13
Works Data, Evaluation of ('47) R-253
Works, Defense Measures for ('43) R-188
Works, Equipment and Tools for ('46) Mag. 150
Works, Financing ('44) R-164, ('47) R-161
Works, Gas Hazards in ('46) R-201
Works Operation Charts ('47) R-249
Works, Public Relations in ('47) R-17
Sewage and Effluent Analyses ('42) R-250
Sewage and Sludge Pumping ('47) R-173
Sewage Plant Records and Operating Reports ('47) R-247
Sewage Sludge as Fertilizer ('45) R-259
Sewage Sludge Digestion Tank Heating ('45) R-215
Sewage Treatment—
Activated Sludge ('44) R-211, ('47) R-191
Activated Sludge Chlorination ('47) R-197, ('47) R-199
Biofiltration ('41) R-189
Copper Sulfate in ('42) R-197
Grease Removal ('41) R-195, ('43) R-211, ('45) R-233
Grit Collection and Washing ('41) R-144, R-156, ('46) R-234
Ferric Salts in ('44) R-235
Kinks ('45) R-181
Plant Operation ('45) R-187, ('46) R-207
Plant Operation, Small ('46) R-209
Plant Records (Logs) ('46) R-214
Processes ('41) R-173, ('44) R-175
Screenings Grinding ('43) R-194
Sludge Digestion ('47) R-213
Sewage Treatment Plant Operation ('45) R-187
Sewage Treatment Processes and Results ('44) R-175
Sewer—
Carrying Capacity ('46) R-266
Cleaning with Beach Balls ('43) R-182
Cleaning, Mechanical ('47) Mag. 249
Design ('44) Mag. 227
Flow Detects Waste Water ('47) R-252
Flushing ('46) R-192
Gases, Control of ('47) R-185
Jointing ('47) R-171
Locating Lost ('46) Mag. 149
Maintenance ('47) Mag. 249, ('46) R-180, R-187, ('47) R-166
Maintenance, with Copper Sulfate ('42) R-197
Manholes (Lost) ('46) Mag. 149
Odors (Traps for) ('47) R-172
Oil Exclusion from ('46) R-195
Pipe Discharge ('46) R-266
Rental ('46) R-177, R-221
Root Control in ('47) R-245
Size and Slope ('44) R-168
Sewerage Financing ('41) R-129
Sewerage Operating Kinks ('45) R-181
Sewer Cleaning with Rubber Beach Balls ('43) R-182
Sewer Flushing ('46) R-192
Sewer Maintenance ('46) R-180
Sewer Odor Traps for Manholes and Inlets ('47) R-172
Sewer Service and Maintenance ('47) R-166
Sheet, Check, Pump Trouble ('46) R-85
Sheet, Lubrication Check ('46) R-213
Sheets, Standard Gauges for ('47) R-86
Shooting Services ('43) R-113
Shop, Small Meter Repair ('46) R-121
Significance, Anthrafilt and Its ('45) R-145
Significance of Sewage Analyses ('42) R-250
Silica and Floc Formation, Colloidal ('44) Mag. 211
Simple Air Sniffer Corrects Pump Pounding ('46) R-84
Simple Method for H_2S Determination ('45) R-263
Simplified Bacteriological Procedure for the Examination of Water ('46) R-171
Single Stage Centrifugal Pumps, Specific Speed Curves for ('46) R-80
Size and Slope of Sewers ('44) R-168
Sizes of Branches and Water Mains, Relative ('47) R-38
Slaking Lime ('45) R-139
Slam, Check Value, Elimination of ('46) R-112
Slide Rule for Sewage Operators ('44) R-184
Slope and Size of Sewers ('44) R-168
Sludge—
Activated (see Activated Sludge)
Blanket Detector ('41) R-230
Bulking (see Activated Sludge)
Conditioning ('47) R-239
Density: Volume Ratio ('44) R-262
Dewatering ('47) R-239
Digester Scum ('47) R-211
Digestion, Per Cent, Chart for ('45) R-257, ('46) R-239
Digestion Tank Heating ('45) R-215, ('46) R-239
Digestion Unit Operation ('47) R-213
Digestion with Garbage ('47) R-217
Fertilizer ('43) R-264, ('45) R-259, ('47) R-229
Filtration Data ('47) R-239
Gas Engines ('45) R-225, R-229, ('47) R-206
Gas Engine Installations ('45) R-229
Gas Engine Power Generation ('46) R-259
Gas Scrubbing ('46) R-261
Handling ('45) R-245
Incineration ('47) R-225
Index Test ('44) Mag. 222
Lagooning ('47) R-231
Pumping ('46) R-219, ('47) R-173
Removal, Cost of ('47) R-227
Sample Preservation ('41) Mag. 231
Solids, Determination ('41) R-222
Sludge as Fertilizer ('47) R-229
Sludge Blanket Detector and Turbidimeter ('41) R-230
Sludge Bulking Controlled by Chlorination ('45) R-212
Sludge Density Control ('47) R-197
Sludge Digester Parts, Corrosion of ('46) R-242
Sludge Digestion Temperature Control with Live Steam ('46) R-239
Sludge Gas Engine Installations in U. S ('45) R-229
Sludge Incineration ('47) R-225
Sludge Index Control by Chlorination ('47) R-199
Sludge Lagooning ('47) R-231
Sludge Pumping ('46) R-219
Small Mains, Compressed Air Flushing of ('46) R-55
Small Mains, Electrical Thawing of ('46) R-40
Small Meter Repair Shop ('46) R-121
Small Pumping Station Operation and Maintenance ('44) R-199
Small Sewage Plant Log ('46) R-214
Small Systems, Iron Removal in ('45) R-141
Small Treatment Plant Operation ('46) R-209
Small Water Plants, Operating Logs for ('45) R-152
Sniffer, Air, Corrects Pump Pounding ('46) R-84
Soap Consumption by Hard Water ('46) R-157
Soapy Waste Waters, Treatment of ('46) R-253
Softening, Water ('46) R-157, ('47) R-141
Solids, Sludge, by Centrifuging ('41) R-222
Solids, Sludge, Rapid Determination of ('46) R-257
Solids, Suspended, Determination of ('45) R-262
Solution Feed Control ('43) R-102
Solution, Lime, Feeding Device for ('46) R-115
Solving a Sewage Pumping Problem ('45) R-256
Solving Chlorine Ice Problems ('47) R-129
Solving Manning's Formula, Nomograph for ('45) R-273
Solving Problems with Electric Heat ('46) R-123
Some Practical Aspects of Handling Chlorine ('47) R-127
Some Relationships Between Current Flow and Heat Production ('45) R-50
Some Sewerage Operating Kinks ('45) R-181
Spacing and Submergence of Suction Bells ('46) R-83
Special Sewer Service Charges for Industrial Wastes ('44) R-166
Specifications, Filter Sand ('46) Mag. 145
Specific Speed Curves ('46) R-80
Speed, Specific Curves ('46) R-80
Spray Ponds, Cooling Towers, Efficiency of ('47) Mag. 252
Sprinkler Head Discharge ('47) R-77
Square Roots, Squares, Circles ('46) R-269
Squares, Roots, and Circles ('46) R-269
Stability Indicator, Enslow Continuous ('46) R-189
Standard Gages for Sheets, Wire, and Plates ('47) R-86
Standard Pipe for Bushings ('47) R-49
Standard Pipes, Safe Columns from ('47) R-170
Standards for Water Service ('45) R-111
Standards, U. S. Drinking Water ('46) Mag. 140
Standpipes and Tanks, Maintenance of ('42) R-89
Station Operation and Maintenance, Small Pumping ('44) R-199
Stations, Maintenance of Sewage Pumping ('47) R-177
Steam Leak Costs ('43) R-282
Steam, Live, for Sludge Digestion Temperature Control ('46) R-239
Steel Surfaces, Cathodic Protection of ('45) R-67
Steel Water Tanks, Cleaning, Painting, Protecting ('45) R-64, R-67, ('47) R-70
Stop Pipe Sweating, To ('45) R-131
Storage, Elevated ('44) R-91, ('46) R-73
Storage, Feeding & Handling Ammonia ('41) R-117
Storage on the Distribution System ('47) Mag. 233
Strainers, Self Cleaning, for Sand Removal from Well Water ('42) R-114
Studies on Infiltration ('47) R-169
Study and Correction of Water Hammer ('47) R-29
Sub-Aqueous Trencher, Air-Lift ('45) R-116
Submergence and Spacing of Suction Bells ('46) R-83
Sub-surface Water, Basic Factors in Pollution of ('46) R-34
Suction Bells, Submergence and Spacing of ('46) R-83
Sulphate, Copper ('45) R-119
Sulphate, Copper, for Killing Roots ('47) R-245
Sulfate, Copper, in Sewer Maintenance ('42) R-197
Sulfide Determination ('40) R-173
Sulfide, Hydrogen Determination ('45) R-263
Sulphur Dioxide, Cleaning Filters with ('46) R-135
Supply in Fire Protection, Water ('43) R-71
Supply Line Capacity Restored by Chlorination ('47) R-55
Surface Area of Cylindrical Objects ('47) R-237
Surfaces, Areas, Volumes, Calculation of ('47) R-276
Surge Troubles on Pump Discharge Lines, Eliminating ('44) R-89
Surveys and Leakage Correction, Water Waste ('44) R-186

REFERENCE AND DATA INDEX — 1941 through 1947

All subjects in this and previous issues are listed with the respective key,—('41), ('42), ('43), ('44), ('45), ('46), or ('47)

Surveys of Waste and Leaks.....('46) Mag. 137
Suspended Solids, Determination of, by Centrifuging.....('45) R-262
Suspensions, Practical Feeder for .....('46) R-175
Sweating, Pipe, To Stop .....('45) R-131
System, Distribution .....('47) R-35
Systems, Distribution, Emergency Repair of.....('43) R-99
Systems, Potable Water, Corrosion Control in.....('46) R-163

T

Table, Metric Conversion .....('46) R-54
Table of Effective Fire Streams .....('47) R-88
Tank Maintenance .....('43) R-80, ('47) R-67, R-70
Tank Protection, Cathodic .....('43) R-83
Tanks—
Capacity .....('45) R-261, R-279, ('47) R-32
Cleaning, Painting, Protecting .....('45) R-64, R-67, ('47) R-70
Digestion, Heating of .....('45) R-215
Elevated Storage .....
.....('44) R-91, ('45) R-64, ('46) R-73, ('47) R-67, R-70
Horizontal, Contents of .....('45) R-261, ('47) R-264
Protecting .....('45) R-64
Maintenance .....('43) R-80, ('45) R-64, ('47) R-67, R-70
Protection, Cathodic .....('43) R-83
Repainting .....('47) R-70
Vertical, Contents of .....('45) R-270
Tanks and Standpipes, Maintenance of.....('42) R-89
Taps from Pipe of Various Sizes.....('45) R-274
Taps, Wet, Method of Making.....('46) R-48
Taste and Odor Control with Activated Carbon.....('47) R-135
Technic in Ground Water Infiltration Studies.....('47) R-169
Temperature Control by Live Steam, Sludge Digestion....('46) R-239
Terminology in Pumping .....('44) R-62
Test for Residual Chlorine, O-T-A .....('45) R-133
Testing Disc Meters at Correct Rates of Flow.....('46) R-117
Testing Water Meters .....('46) R-116
Thawing, Electrical .....('46) R-40
Thawing Hydrants, Method of .....('46) R-42
Theoretical Horsepower .....('45) R-283
Theory and Operation of Separate Sludge Digestion Units.('47) R-213
Thermal Conductivity of Insulating Materials.....('47) R-64
Thickening, Activated Sludge .....('43) R-243
Those Plus Values of Sewage Sludges.....('43) R-264
Time Saving Calculator .....('44) R-43
Today's Costs of Water Main Extensions.....('47) Mag. 229
Tools and Equipment for Sewage Works.....('46) Mag. 150
To Stop Pipe Sweating .....('45) R-131
Total Solids in Sludge by Centrifuge Method.....('41) R-222
Trap, Fume, for Internal Combustion Engines.....('42) R-20
Traps for Odors from Sewer Manholes and Inlets.....('47) R-172
Treating Incrusted Wells .....('46) R-23
Treating Water to Prevent Corrosion.....('45) R-148
Treatment of Soapy Waste Waters .....('46) R-253
Treatment of Water with Calgon .....('45) R-151
Treatment of Water with Chlorine Dioxide.....('45) R-129
Treatment Plant Odors, Control of .....('47) R-185
Treatment Plant Operation, Relation of Hourly Load Variation to .....('46) R-207
Treatment Plant Operation, Sewage .....('45) R-187
Treatment Processes and Results, Sewage.....('44) R-175
Treatment Processes, Sewage, in Brief.....('41) R-173
Trencher, Sub-aqueous Air-Lift .....('45) R-116
Trenching Practice .....('46) R-27
Trickling Filter Nozzle Replacement .....('46) R-214
Trituration of Sewage Screenings .....('43) R-194
Trouble, Pump, Check Sheet .....('46) R-85
Truck, Power Crane .....('47) R-54
Tuberculation, Checking, by Chloramine Treatment.....('46) R-57
Tuberculation Measurement as an Index of Corrosion and Corrosion Control .....('47) R-155
Turbidimeter, Sludge Blanket .....('41) R-230

U

Unbilled Revenue and Accounted for Water.....('45) R-109
Underground Water Cooling Scheme of Atlanta Water Dept. .....('43) R-108
Underwriters, National Board, Fire Flow Table.....('46) R-64
Uprating Distribution Systems by Cleaning and Cement Lining .....('46) R-51
U. S. Drinking Water Standards.....('46) Mag. 140
Use and Handling of Chlorine .....('47) Mag. 253
Useful All Purpose Pipe Chart.....('46) Mag. 160
Usefulness of Copper Sulfate.....('45) R-119
Useful Technic in Ground Water Infiltration Studies....('47) R-169
Use of Charts in the Analysis of Sewage Works Operation.('47) R-249
Use of Inhibitors in Cleaning Metallic Pipe.....('46) R-161

V

Vacuum Filter Dressing Rig.....('42) R-242
Vacuum Filters, Encrusted, Cleaning with Acid.....('46) R-241
Value of Elevated Tanks.....('46) R-73
Values, Fertilizer of Sewage Sludge.....('46) R-249
Values of Sewage Sludge, Fertility.....('43) R-264
Valve Care and Maintenance, Gate.....('47) R-84
Valve, Friction Chart for.....('47) R-52
Valve, Slam, Elimination of Check.....('46) R-112
Valves, Loss of Head Through.....('42) R-69
Variations, Hourly Load in Sewage Plants.....('46) R-207
Velocities, Controlling Grit Chamber.....('40) R-138
Velocity and Discharge Diagram for Vitrified Clay Sewer Pipe .....('42) R-193
Velocity Control in Grit Channels.....('47) R-180
Velocity in Pipes.....('46) R-276
Vertical Cylinder and Tank Contents.....('47) R-264
Vitrified Clay Sewer Pipe, Velocity and Discharge in....('42) R-193
V-Notch Weirs, Capacity.....('47) R-272
Volume Demand and Rates of Flow for Various Uses and Fixtures .....('45) R-117
Volumes, Surfaces, Areas, Calculation of.....('47) R-274
Volume to Density Ratio in Sludge.....('44) R-262

W

Wall Panel, for Treatment Plants.....('47) R-228
Washer and Ejector, Grit.....('46) R-234
Washing Filters.....('44) R-151
Washing Grit.....('41) R-156
Waste, Blotting Out.....('47) R-93
Waste Oil, Exclusion of, from Sewers.....('46) R-195
Waste Surveys, and Leakage Correction, Water.....('44) R-105
Waste Water Detection in Sewer Flows.....('47) R-252
Waste Waters, Soapy, Treatment of.....('46) R-253
Waste Water Surveys.....('46) Mag. 137
Water—
Accounted for.....('45) R-109
Analyses .....('46) R-148
And Mercury Equivalents.....('47) R-176
And Sewer Rental (Joint).....('46) R-177, R-221
Bacterial Examination of .....('45) R-155, ('46) R-171
Characteristics of Natural.....('46) R-146
Chemicals, Weights of Dry.....('47) R-64
Costs at Stated Rates.....('47) R-126
Flow (See Flow)
Hammer .....('45) R-53, ('46) R-106, R-112, R-113, ('47) R-29
Hammer and Check Valve Slam.....('46) R-112
Infiltration Studies.....('47) R-169
Leak Costs.....('47) R-200
Main Branches.....('47) R-38
Main Cleaning.....('47) R-78
Main Cleaning with Compressed Air.....('47) R-81
Main Extensions.....('47) Mag. 229
Meters (See Meters)
Operator, Legal Responsibilities of.....('46) R-18
Plant Logs.....('45) R-152
Quality Control by Calgon.....('45) R-151
Pipes (See Pipe)
Piping in Buildings.....('45) R-19
Pitometer Surveys (See Waste Surveys)
Pressure .....('43) R-41
Rates and Costs.....('47) R-126
Requirements for Fixtures.....('47) R-92
Sand Removal.....('42) R-114
Sanitation Practice Manual.....('43) R-128
Service Lines, Blowing Out.....('46) R-54
Service Standards.....('45) R-111
Softening .....('46) R-153, R-157, ('47) R-141
Stability Indicator.....('46) R-169
Standards .....('46) Mag. 140
Storage, Elevated.....('46) R-73, ('47) R-70
Sub-surface, Pollution of.....('46) R-24
Tanks (See Tanks)
Treatment (See Water Treatment)
Utility Profit Sharing Plan.....('46) Mag. 143
Waste .....('47) R-93
Waste Detection.....('47) R-252
Waste Leakage Correction.....('44) R-105
Waste Surveys.....('41) R-89, ('46) Mag. 137
Wells (See Wells)
Works, Books on.....('46) R-13
Works Depreciation .....('47) Mag. 237
Works Equipment.....('42) R-109
Works Land Reforestation ..... ('47) R-13
Works Management .....('43) R-21
Works Operation .....('46) R-15
Works, Public Relations in.....('47) R-17

REFERENCE AND DATA INDEX — 1941 through 1947

All subjects in this and previous issues are listed with the respective key,—('41), ('42), ('43), ('44), ('45), ('46), or ('47)

Water at Your Tap at Less Than 5c Ton.....('42) R-123
Water Flow Through Pipes.....('45) R-274
Water Hammer
....('44) R-66, ('45) R-53, ('46) R-106, R-112, R-113, ('47) R-29
Water Hammer Corrections.....('46) R-106
Water Main Cleaning.....('47) R-78
Water Meter Maintenance Practice.....('42) R-121
Water Meter Testing, Principle and Practice.....('46) R-116
Water Pressure—Head to Pounds.....('45) R-283
Water Requirements.....('47) R-92
Water Service and Sewer Rents.....('46) R-221
Water Service Standards.....('45) R-111
Water Softening.....('46) R-157
Water Supply in Fire Protection.....('43) R-71
Water Supply Pipe, Gallons in (Nomograph).....('42) R-274
Water Treatment—
Aqua Ammoniation.....('41) R-95
Calgon.....('45) R-151
Chlorine Dioxide.....('45) R-129
Coagulation, Aided by Silica.....('44) Mag. 211
Coagulation with Ferric Salts.....('44) R-235, ('46) Mag. 147
Copper Sulfate.....('45) R-119
Corrosion Control.....('46) R-163
Corrosion Prevention by.....('45) R-148
Ferric Salts Coagulation.....('46) Mag. 147
Ferric Salts in.....('44) R-235
Iron Removal.....('45) R-141, ('46) R-153
Manganese Removal.....('44) R-147, ('47) R-159
Softening.....('46) R-153, R-157
Water Waste Surveys.....('41) R-89
Water Waste Surveys and Leakage Correction.....('44) R-105
Watt-Hour Meters, Computing Horsepower from.....('46) R-114
Weed Control, Chemical.....('47) R-121
Weight Determination of Settleable Sewage Solids.....('46) R-208
Weights and Measures.....('47) R-264
Weights of Materials.....('46) R-170
Weights per Cubic Foot of Dry Chemicals.....('47) R-64
Weirs, Capacity of—
Rectangular.....('47) R-273
V-Notch.....('47) R-272
Well Cleaning and Rehabilitation.....('47) R-107
Wells—
Capacity, Maintenance of.....('47) R-109
Capacity Recovered with Chlorine.....('47) R-112
Cleaning.....('47) R-107
Development of Rock.....('45) R-51, ('46) R-21
Drilling of.....('46) R-21
Incrusted, Treating.....('46) R-23
Pumps.....('47) R-113
Rating & Sampling.....('45) R-47
Water, Sand in.....('44) R-149
Water, Sand Removal from.....('42) R-114
Well Water Sand, Determination of.....('44) R-149
Wet Taps, Method of Making.....('46) R-48
What Leaks Cost.....('47) R-200
Where the Water Dollar Goes.....('45) R-39
Wire, Standard Gages for.....('47) R-86
Wooden Beams, Safe Loading for.....('45) R-280

Y

Yardage on Reels or Drums, Determining.....('47) R-212

Z

Zones, pH in Water and Sewage Treatment.....('43) R-285

AUTHOR INDEX — REFERENCE AND DATA SECTION 1941 through 1947

A

Abrams, Allen and Wagner, C. L. .....('46) R-161
Ackerman, J. Walter .....('46) R-57
Adams, J. Kenneth .....('47) R-199
Albert, Paul McH. .....('45) Mag. 201, ('45) R-278
Alexander, L. J. .....('47) R-113
Amsbary, Frank C., Jr. .....('46) R-40
Anderson, C. George .....('46) R-180
Angus, Robert W. .....('46) Mag. 125, R-75, ('47) Mag. 245
Applebaum, S. B. .....('47) R-141
Arbuthnot, J. R. .....('47) R-42

B

Backmeyer, David .....('45) R-229, ('47) R-217
Baffa, John J. .....('47) R-39
Banta, A. P. .....('45) R-187
Barbee, Edwin W. .....('47) R-155
Barker, Stanley T. .....('40) R-138
Barry, W. Vincent .....('47) R-249
Baylis, John R. .....('45) R-148
Beckwith, H. E. .....('47) R-21
Bennett, Richard C. .....('43) R-71, ('46) R-27, R-106
Bernauer, G. F.; Warrick, L. F. and .....('47) R-235
Bingham, Chris F. .....('47) R-127
Bloodgood, Don .....('41) R-230, ('44) Mag. 222, ('47) R-231
Brossman, Charles .....('46) R-73
Brown, Carl B. .....('41) Mag. 267
Brown, R. F. .....('46) R-55, ('47) Mag. 249
Brown, Thomas and Preston, George .....('45) R-225
Bunker, George C. .....('44) R-149
Burdick, Charles B. .....('47) Mag. 233
Burley, Fred H. .....('46) R-256
Burr, Francis K. .....('44) R-235
Bushee, Ralph J. .....('47) R-180

C

Calderwood, Don C. .....('46) R-20, ('47) R-111, R-129
Carr, J. Arthur .....('45) R-51, ('46) R-21
Carr, Ralph L. (See Quinn, R. J.)
Clark, H. W. .....('45) R-83
Cody, B. L. .....('44) R-63
Cole, E. Shaw .....('46) Mag. 137
Cunningham, M. B. .....('40) Mag. 165
Cook, H. J. .....('42) R-118
Coventry, F. L. (See Goetz, John A.)
Cranch, E. T. .....('46) Mag. 149, R-48, R-115, ('47) R-87
Crawford, H. V. .....('47) R-215

D

Davis, S. H. .....('47) R-99
Davis, Walker B. .....('43) R-80
Dawson, F. M. and Kalinski, A. A. .....('45) R-233
Decher, Edward P. .....('47) R-166
Dodd, C. I. .....('46) R-56
Doman, Joseph .....('47) R-211
Donaldson, W. .....('47) R-120
Drier, Douglas E. .....('45) R-202

E

Edwards, A. M. .....('44) R-111
Edwards, Gail P. .....('47) R-191
Edwards, S. E. and McCall, G. B. .....('47) R-159
Eisner, Benjamin .....('44) R-204
Eliassen, Rolf .....('45) R-211, ('46) R-163
Enslow, L. H. .....('46) R-13, R-225
Esty, Roger W. .....('46) R-119, R-121, ('47) R-94

F

Faber, Harry A. .....('47) R-131
Fabrin, Axel O. .....('46) R-87
Fischer, A. J. .....('41) R-189
Fischer, A. J. and Hillman, A. .....('46) R-141
Fischer, A. J. and Symons, George E. .....('46) R-206
Fischer, Curt R. .....('47) R-101
Flood, Frank L. .....('41) R-195
Frank, J. A. .....('46) R-51
Franklin, W. M. .....('44) R-221
Fugate, G. L. .....('42) R-114
Fuller, Harry V. .....('45) R-116
Fuller, Nelson M. .....('46) R-234

G

Gard, Charles M. .....('47) R-239
Gehm, Harry W. .....('46) R-253
Gibson, James E. .....('45) R-56
Gifft, H. M. .....('45) R-40, R-156
Gilbert, J. J. (See Tark, M. B.)
Gilcreas, F. W. .....('45) R-133
Glace, I. M. (See Krum, H. J.)
Glover, W. W. .....('45) R-256
Goehring, E. C. .....('43) R-155
Goetz, John A. .....('44) R-164
Goetz, John A. and Coventry, F. L. .....('46) R-22
Goff, Wm. A. .....('47) R-171
Goudey, R. F. .....('47) R-103, R-131

AUTHOR INDEX — REFERENCE AND DATA SECTION
1941 through 1947

Gross, D. D. ..... ('47) R-252
Gunderson, N. E. ..... ('47) R-109
Gwyther, R. E. ..... ('47) R-72

H

Haentjens, W. D. ..... ('46) R-78
Hale, Frank E. ..... ('46) R-173
Hanes, G. C. (See Nester, N. W.)
Hazeltine, T. R. ..... ('45) R-197
Hatfield, W. D. (See Phillips, George)
Hay, Harold R. ..... ('44) Mag. 211
Hechmer, Carl A. ..... ('40) R-96
Hedgepeth, L. L. and Potter, J. M. ..... ('44) R-241
Hess, Seth G. ..... ('43) R-188, ('46) Mag. 150
Heukelekian, H. ..... ('42) R-203
Hillman, A. (See Fischer, A. J.)
Hirsch, A. A. .....
...('44) R-184, ('45) R-50, R-154, ('46) R-33, R-67, R-167, R-214
Hommon, Chas. C. ..... ('47) R-185
Hood, John W. ..... ('42) R-197
Hoover, Chas. P. ..... ('45) R-131, R-144, ('46) R-157
Horn, W. Walter ..... ('47) R-89
Hotchkiss, Henry T. ..... ('46) R-139
Howard, Paul F. ..... ('45) R-47
Howard, Roscoe R. ..... ('47) R-81
Howland, W. E. ..... ('47) R-182
Howson, Louis R. ..... ('43) R-21, ('46) R-15, ('47) R-35
Hunter, Charles A.; Patty, Eleanor, and McKinley, Flora.. ('46) R-171
Huston, W. E. ..... ('47) R-112

J

Jackson, L. A. and Mayhan, W. A. ..... ('47) R-55
Jacobson, E. E. ..... ('46) R-42
Jenkins, Edward J. ..... ('46) R-145

K

Kalinski, A. A. (See Dawson, F. M.)
Kappe, S. E. ..... ('46) R-219
Keefer, C. E. ..... ('46) R-195
Keith, Donald R. ..... ('45) R-274, ('46) R-266
Killam, Elson T. ..... ('46) R-207, ('47) R-225
Kin, Stephen R. ..... ('45) R-212
Kin, Stephen R. (See Symons, George E.)
King, Arthur C. ..... ('46) R-48
King, Henry R. ..... ('44) R-205
Kivell, W. A. and Lund, N. B. ..... ('41) R-144
Kozma, Albert B. ..... ('46) R-235
Kraus, L. S. ..... ('47) R-205
Krum, H. J. and Glace, I. M. ..... ('44) R-151
Kuranz, Arthur P. ..... ('42) R-121, ('46) Mag. 143

L

LaDue, Wendell ..... ('46) R-124, ('47) R-13, R-91
Langford, L. L. ..... ('47) R-213
Lanphear, Roy S. ..... ('46) R-214
Larson, T. E. ..... ('47) R-116
Lauge, Carl J. ..... ('41) R-95
Leveque, R. J. ..... ('47) R-64
Liepold, Carl ..... ('45) R-18
Lenth, Geo. C. D. ..... ('42) R-193
Lordley, H. E. ..... ('45) R-139, R-141
Lucoff, Julius ..... ('46) R-193
Lund, N. B. (See Kivell, W. A.)

M

Malcolm, W. L. ..... ('44) Mag. 227
Martin, George ..... ('45) R-263
Mathis, Alice L. ..... ('45) R-262
Mavis, F. T. ..... ('44) R-262
Mayhan, W. A.; Jackson, L. A. and ..... ('47) R-55
Melas, William ..... ('41) Mag. 289
Mick, K. L. ..... ('46) R-241
Monie, Wm. D. ..... ('47) R-118
Montgomery, James M. ..... ('45) R-37, ('46) R-148
Moore, Chas. E. ..... ('45) R-109
Morgan, L. S. ..... ('47) R-247
Moseley, Alex W. ..... ('46) R-113
Murdoch, John H., Jr. ..... ('47) Mag. 237
MacMahon, J. D. (See Synan, J. F.)
MacMurray, L. C. ..... ('46) R-24
McAmis, J. W. ..... ('47) R-245
McCall, G. B.; Edwards, S. E. and ..... ('47) R-159
McKinley, Flora (See Hunter, Charles A.)
McLoughlin, Charles A. ..... ('47) R-170

N

Nester, N. W. and Hanes, G. C. ..... ('45) Mag. 207
Neubling, Emil L. ..... ('45) R-266
Nickel, J. B. ..... ('46) Mag. 147
Nichols, R. D. ..... ('41) R-156
Niles, A. H. ..... ('45) R-259
Norman, Earl E. ..... ('43) R-83

O

Olewiler, G. M. ..... ('44) R-199
Opie, Vester ..... ('46) R-175

P

Palen, V. W. ..... ('44) R-43
Palmer, H. K. ..... ('46) R-112
Parkes, G. A. ..... ('46) R-242
Patrick, J. G. ..... ('46) R-135
Patty, Eleanor (See Hunter, Charles A.)
Perryman, John M. ..... ('45) R-64, ('47) R-67
Phillips, Geo. and Hatfield, W. D. ..... ('41) Mag. 285
Phillips, Robert S. ..... ('44) R-147, ('46) R-169
Pomeroy, Richard ..... ('40) R-173, ('42) R-250
Pond, A. M. ..... ('45) R-117
Poston, H. W. ..... ('45) R-155, R-159
Potter, J. M. (See Hedgepeth, L. L.)
Preston, George (See Brown, Thomas)

Q

Quinn, R. J. and Carr, Ralph L. ..... ('41) R-117

R

Radcliffe, D. M. ..... ('44) R-66
Rapp, W. M. ..... ('44) R-75
Rawn, A. M. .....
('41) R-173, ('43) R-182, R-264, ('45) R-181, ('46) R-238, R-239
Regester, Robert T. ..... ('45) R-34
Reny, F. J. ..... ('47) Mag. 229, ('47) R-100
Rice, Owen ..... ('45) R-151
Richardson, A. C. ..... ('46) R-83
Riddick, Thomas M. ..... ('46) Mag. 145, R-103, ('47) R-149
Roe, Frank C. ..... ('46) R-230
Rogers, Sherman L. ..... ('42) R-109
Rudolfs, Willem ..... ('46) R-249
Ruehl, E. H. ..... ('47) R-75
Ryon, Henry ..... ('45) R-249, ('47) R-29, R-173

S

Saunders, Daniel J. ..... ('46) R-153
Schaphorst, W. F... ('40) R-200, ('42) R-270, R-274, R-278, ('43)
R-283, ('44) R-184, ('45) R-46, R-235, R-280, R-281, ('46)
Mag. 160, R-77, ('47) Mag. 252, R-69, R-170, R-212, R-230, R-237
Sheets, W. D. ..... ('42) R-242
Sigworth, E. A. ..... ('47) R-135
Smith, E. E. ..... ('42) R-202
Smith, Marsden C. ..... ('45) R-111, ('47) R-59
Snell, J. R. ..... ('47) R-246
Soden, A. L. ..... ('47) R-177
Sperry, W. A. ..... ('47) R-17, R-227
Stalker, A. D. ..... ('41) R-89
Staub, William S. ..... ('42) R-89, ('47) R-78
Sudrabin, Leon P. ..... ('45) R-67
Symons, George E. ..... ('44) R-175, ('47) R-243, R-253
Symons, George E. and Crane, Frederick W. ..... ('44) R-166
Symons, George E. and Kin, Stephen R. ..... ('46) R-257
Symons, George E. and Torrey, Wm. L. ..... ('41) R-222
Symons, George E. (See Fischer, A. J.)
Synan, John F., MacMahon, J. D. and Vincent, G. P. .... ('45) R-129

T

Tapleshay, John A. ..... ('47) R-197
Tark, M. B. and Gilbert, J. J. ..... ('41) R-152
Tarrant, J. ..... ('45) R-191, R-270
Taylor, D. R. ..... ('42)
R-104, R-128, ('43) R-51, ('46) Mag. 129, R-37, R-84, ('47) R-54
Taylor, Stephen H. ..... ('45) R-19
Tempest, W. F. ..... ('41) R-129
Thompson, Leonard N. ..... ('46) R-177
Thoresen, T. C. ..... ('44) R-45
Torrey, Wm. L. (See Symons, George E.)
Travaini, Dario ..... ('43) R-243
Trentlage, La Verne ..... ('43) R-113
Turner, H. G. ..... ('45) R-145
Tyler, Richard G. ..... ('40) R-44

U

Urban, Robt. C. ..... ('46) R-213
U. S. Public Health Service ..... ('43) R-125

V

Van Horn, W. (See Warrick) ..... ('44) R-127
Van Kleeck, Le Roy W. ..... ('47) R-229
Veatch, N. T. ..... ('45) R-15
Velzy, Chas. R. ..... ('45) R-245
Vincent, G. P. (See Synan, John F.)

W

Wagner, C. L. (See Abrams, Allen)
Warrick, L. F. and Bernauer, G. F. ..... ('47) R-235
Warrick, L. F., Wirth, H. E., and Van Horn, W. ..... ('44) R-127
Watkins, William W. ..... ('43) R-194
Watson, John D. ..... ('46) R-192
Weber, C. G. ..... ('46) R-209
Wenrick, H. P. ..... ('47) R-107
Weir, Paul ..... ('45) R-119, ('46) R-127
Weir, W. Victor ..... ('43) R-99
Whitman, N. D. ..... ('44) R-263, ('46) R-271
Wiest, Gordon J. ..... ('43) R-211, ('44) R-252
Wilson, Carl ..... ('46) R-146
Wilson, E. K. ..... ('44) R-105
Wilson, P. S. ..... ('45) R-43, ('46) R-117
Wirth, H. E. (See Warrick)
Wirts, John J. ..... ('47) R-201
Wisely, W. H. ..... ('44) R-211, ('46) R-187
Wittwer, Norman C. ..... ('45) R-215, ('46) R-259, ('47) R-255

Total Pages This Issue—434

Index TO ADVERTISERS

For the Classified Index of Products See Page R-2

A

Albert Pipe Supply Co. 132
Albright & Friel, Inc. 138
Allis-Chalmers R-26-27
Alvord, Burdick & Howson 138
American Brass Company, The 6
American Concrete Pipe Ass'n 44
American Hard Rubber Co. R-98
American Radiator & Standard Sanitary Corp. 137, R-216
Amer. Water Softener Co. 134
American Well Works 16
Anthracite Equipment Co. 136, R-146
Argraves & Mort 138
Atlas Mineral Products Co. of Pa., The R-34
Automatic Control Co. 134

B

Badger Meter Mfg. Co. 33
Bailey Meter Co. R-190
Baker, Jr., Michael 138
Barrett Haentjens & Co. 122
Betz, W. H. & L. D. 135
Black & Veatch 138
Blaw-Knox Co. 113
Bogert-Childs 138
Bowe, Albertson & Assoc. 138
Buck, Seifert and Jost 138
Buffalo Meter Co. 112
Builders-Providence, Inc. 108, R-74
Builders Iron Foundry 108, R-74
Burns & McDonnell 138
Byers Co., A. M. 41
B/W Controller Corp. 113, R-117

C

Calgon, Inc. 60, R-148
Camp, Dresser & McKee 138
Carborundum Co., The 29
Carson Cadillac Co. 136
Carter Company, Ralph B. 131
Cast Iron Pipe Research Ass'n 18-19
Cement Gun Co. 127
Central Fdry. Co., The 113
Centriline Corp. 25
Chain Belt Company 10
Chester Engineering, The 138
Chicago Bridge & Iron Co. 7
Chicago Pump Company 107, R-196
Chapman Valve Mfg. Co., The ..... Inside Front Cover
Clark Controller Co. R-20
Cloroben Corp., The 58
Cole Manufacturing Co., R. D. R-66
Columbia Chemical Division 11
Crane Co. 20

D

Davey Compressor Co. 17
Dean & Co., Payne 127
De Laval Steam Turbine Co. 12-57
DeLeuw, Cather & Co. 138
Diamond Alkali Company 43
Dorr Company, Inc., The ..... Third Cover
Dracco Corp. 109
Drake Mfg. Co. 137
Dresser Manufacturing Co. 35

E

Eddy Valve Company 53
Edson Corporation, The 137
Electronic Purification Co. 123
Everson Mfg. Co. 135

F

Fairbanks-Morse 22
Fay, Spofford & Thorndike 138
Federal Telephone & Radio Corp. 30
Filer & Stowell Co. 121
Fitzgerald, J. C. ..... Facing R-161
Flexible Sewer Rod Equipment Co. 125
Flexible Underground Pipe-Cleaning Co. 124
Ford Meter Box Co. 110

G

Gannett, Fleming, Corddry & Carpenter, Inc. 138
General American Transportation Corp. 37
General Chemical Co. 21
Gilbert Associates, Inc. 138
Glace, I. M. 138
Glauber Brass Mfg. Co. 133
Goff, Wm. A. 138
Golden-Anderson Valve Spec. Co. 130, R-44
Gorman-Rupp Co., The 28
Greeley & Hansen 138

H

Hardinge, Inc. R-210
Havens & Emerson 138
Hayden, Harding & Buchanan 138
Haydock, Chas. 139
Hayman & Co., Michael 135
Hays Mfg. Co. 118
Hellige, Inc. 135, R-261
Hooker Electrochemical Co. R-242
Hydraulic Development Corp. 8-9
Hydrauger Corp. 113

I

Industrial Chemical Sales Co. 23
Inertol Co., Inc. 137
Infilco, Incorporated 49, R-138-139
Innis, Speiden & Co. R-238

J

Jaeger Machine Co. 47
Jeffrey Manufacturing Company 61, R-222-223
Johns-Manville 38-39, R-94-95-96-97
Johnston & Jennings Co. 127
Jones & Henry 139
Josam Manufacturing Co. 46

K

Kennedy, Clyde E. 139
Klett Mfg. Co. 123
Knowles, Inc., Morris 139

L

LaMotte Chemical Products Co. 131
Layne and Bowler, Inc. 130
Leadite Company 132
Leopold, Inc., F. B. 132, R-137
Link-Belt Company R-188-189
Liquid Conditioning Corp. 111
Lock Joint Pipe Co. 64
Lozier, Inc., Wm. S. 139
Ludlow Valve Mfg. Co. 34

M

M. & H. Valve & Fitting Co. 111, R-83
Mathews Hydrants 27
Mathieson Alkali Co. 63
Metcalf & Eddy 139
Meter Specialty Co. 136
Moore & Owen 139
Morris Machine Works 119
Mueller Company 59

N

National Clay Pipe Mfrs., Inc. 48
National Technical Laboratories 45
National Water Main Clean. Co. 50
Neptune Meter Company 66
Nichols Engr. Research Corp. R-224
Northrop & Co., Inc. 136
Nussbaumer & Clarke, Inc. 139

O

Oakite Co. 132
Omega Machine Co. 61, R-134

P

Pacific Flush-Tank Company 124
Parsons, Brinckerhoff, Hogan & MacDonald 139
Payne Dean & Co. 127
Peerless Pump Division 116
Pennsylvania Salt Mfg. Company 15
Permutit Co., The 120, R-140
Philadelphia Quartz Co. 115
Phipps & Bird, Inc. 129
Pirnie, Malcolm 139
Pitometer Co., The 139
Pittsburgh-Des Moines Steel Co. R-65
Pittsburgh Equitable Meter Company... 3
Pittsburgh Plate Glass Co. 11
Preload Corp. 56
Proportioneers, Inc. 62, R-241
Purcell, Lee T. 139

R

Regester, Robt. T. 139
Rensselaer Valve Co. 14
Richmond Fdry. & Mfg. Co. 134
Riddick, Thomas M. 139
Robert and Co. 139
Rockwell Mfg. Co. 3
Roberts Filter Mfg. Co. 12
Roots-Connersville Blower Corp. 117
Ross Valve Mfg. Company R-28
R-S Products Corp. 32, R-25
Roy Co., Milton 54
Royer Foundry & Mach. Co. 114
Russell & Axon 139
Rusta Restor 137

S

Sanequipment Engr. 130
Sargent, Lester L. 139
Sergeant Pulp & Chemical Co., Inc. 136
Servicised Products Corp. 24
Simplex Valve & Meter Co. 140, Facing R-1
Sirrine & Company, J. E. 139
Skasol Corp. 135
Smith Mfg. Co., The A. P. 36
Smith & Associates, Benj. L. 139
Smith Co., S. Morgan 42
Solvay Sales Corp. 126
Sparling, R. W. R-77
Stanley Engineering Company 139
Stewart, M. C. 136
Stewart, W. H. 121
Streander & Affiliates, Phil. B. 139
Stuart Corp. 136, R-147

T

Tennessee Corporation 54
Thomson Meter Co. 66

U

U. S. Pipe & Fdry. Co. 55, R-30

V

Valve and Primer Corp. R-33
Vapor Recovery Systems Co. R-204
Vogt Brothers Manufacturing Co. 134
Vogt Manufacturing Co. 134

W

Walker Process Equip. Inc. 124
Wallace & Tiernan Co., Inc. ..... Back Cover, R-130-134
Werfelman Co., The Geo. H. 58
Warren Foundry & Pipe Corp. 129
Westinghouse Electric Corp. 4-5
Weston, L. A. 136
Weston and Sampson 139
Whitman and Howard 139
Whitman, Requardt & Assoc. 139
Wood Company, R. D. 27
Wood & Preuit Co. 123
Worthington-Gamon Meter Co. 40
Worthington Pump & Machy. Corp. ... 63

Z

Zeolite Chemical Co. 31

*A two-color four page leaflet . . . just off the press . . . highlighting the mechanical and operating details of the new Dorr Duo-Clarifier and Dorrco Duo-Filter. Write for your copy now.**

. . . . yours for the asking . . . .

DORRCO

Small scale Biofiltration

with the

DORR DUO-CLARIFIER

and the

DORRCO DUO-FILTER

The Dorr Duo-Clarifier, combined with the Dorrco Duo-Filter and pumping units, provides complete two-stage Biofiltration treatment in two structures instead of the usual four. The Duo-Clarifier provides primary and secondary sedimentation in one structure and the Duo-Filter, with first and second stage filters concentrically arranged, provides two-stage filtration in a second single structure. One Clarifier mechanism and one Rotary Distributor are the only items of equipment necessary, aside from pumps and a digester.

Leaflet No. 7312

THE DORR COMPANY

Engineers — 570 LEXINGTON AVENUE, NEW YORK 22, N. Y.

OTHER ADDRESSES ON BACK COVER

*** Better still . . . visit Booths 123-126 inclusive at the AWWA/FSWA Convention at San Francisco, July 21-25 and see our exhibit on this and other new developments.**

THE GOLD RUSH OF '47

No, we didn't get our dates mixed. It's just that while the rush of '49 brought fame and fortune to only a few, EVERYONE attending the combined AWWA-FSWA Meeting in San Francisco in '47 can pick up pay dirt from the biggest strike ever made.

There'll be a rich vein of technical papers and exhibits mined for you by experts who'll be glad to help you pick out just the nugget of information or piece of equipment you need to make your own "mining" easier and more effective.

In our part of the lode—Booths 36 to 41—we'd like to show you Visible Vacuum Chlorinators — Hypochlorinators — Dry Chemical Feeders — Chlorine Flow and Residual Recording Equipment — The Program Controlled Sewage Chlorinator — Electro Rust-Proofing Cathodic Protection Equipment—and other water and sewage equipment all ready for prompt delivery and all designed to make your job easier and more effective.

5-12

WALLACE & TIERNAN COMPANY, INC.

MANUFACTURERS OF CHLORINE AND AMMONIA CONTROL APPARATUS

NEWARK 1, NEW JERSEY • REPRESENTED IN PRINCIPAL CITIES